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ADDRESS

DELIVERED AT

THE ANNIVERSARY MEETING

OF THE

GEOLOGICAL SOCIETY OF LONDON,

On the 16th of FEBRUARY, 1877;

PREFACED BY

THE ANNOUNCEMENT OF THE AWARD

OF

THE WOLLASTON MEDAL,

THE PROCEEDS OF THE DONATION-FUND,

THE MURCHISON MEDAL

AND GEOLOGICAL FUND,

THE LYELL MEDAL AND FUND,

AND

THE BIGSBY MEDAL

FOR THE SAME YEAR.

BY PROFESSOR P. MARTIN DUNCAN, M.B. (LOND.), F.R.S.,
PRESIDENT OF THE SOCIETY.

LONDON:
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PROCEEDINGS

AT THE

ANNUAL GENERAL MEETING,

16TH FEBRUARY, 1877.

AWARD OF THE WOLLASTON MEDAL.

The Reports of the Council and of the Library and Museum Committee having been read, the President, Prof. P. MARTIN DUNCAN, M.B., F.R.S., presented the Wollaston Gold Medal to Mr. ROBERT MALLET, C.E., F.R.S., F.G.S., addressing him as follows:—

MR. MALLET,—

The Council of the Society has awarded you its principal Medal, which, originating with the illustrious Wollaston, has year by year received an increasing value by its reception by the most distinguished Geologists in the world. This now famous prize is presented to you in recognition of the results of at least forty years of sedulous labour in some of the most important and difficult problems in Geology. Early in your career you commenced those studies relating to Earthquakes and Volcanoes which have occupied your time and taxed your energies down to the present date. From the first you took the correct logical method of investigation of phenomena which were hardly disconnected from the supernatural; you collected the facts and indicated the manner in which you would employ them by your communications "On the Relation of Molecular Forces to Geology," and "On the Dynamics of Earthquakes, or an attempt to reduce their observed phenomena to the known laws of Wave-motion in Solids and Fluids." Moreover your reports "On the Experimental Determination of the limits of the transit-rate of the propagation of waves or pulses analogous to those of Earthquakes through Solid Materials," and on the results of your experiments on a cognate subject on the rocks of Holyhead, tended to prepare science for your theories of the Earthquake-wave, and for the establishment of that branch of knowledge which owes so much to you, namely Seismology. Your numerous reports to the British Association for the Advancement of Science upon Earthquakes, and your magnificent contribution to Science and Literature upon the Neapolitan Earthquake, added immensely to the knowledge of the subject; and your descriptions of the nature of the earth-movement, of the comparatively slight depth of the focus of motion, and of the nature and effects of the great marine wave, have been pregnant with results in geological theory. Of late years your able communication to the Royal Society "On Volcanic Energy" has been very prominently before the physicists and geologists of the Old and the New World. Full of admirably elaborated facts, it propounds a theory whose truth may be fairly estimated by the constant attention it has received. One of your earliest communications was "On the Trap-rocks of Galway," and your latest have been on the same subject. In your last essay you have endeavoured to solve the difficult question of the peculiar shape of the basaltic prisms. In all these researches your employment of the exact sciences has been of necessity; and it is evident that the procedure has not only been most satisfactory in your argument, but that it has afforded a good example to those who cannot pretend to be geologists without an acquaintance with your works. You have followed out the line of research with which you commenced, and have done great service to geology, and also in directing the thoughts of scientific men towards the cosmical relations of the grandest phenomena of the globe, and the possibility of their explanation by thermodynamics. As a student of your works, and as a teacher of your views, I am proud of having this opportunity of conferring upon you this well-merited reward.

Mr. Mallet, in reply, said:—

Mr. President,—

I am deeply sensible of the great honour which has been conferred upon me by the award of this Wollaston Medal, the highest honour which it is in the power of the Society to bestow. I appreciate this honour as of the greater significance, since of all our scientific societies the Geological Society of London must be deemed that which in all respects is the most competent to form a judgment of those labours it has specifically named as justifying its decision in my own case. It is a somewhat trying ordeal, even to one of far greater eminence than I can pretend to, to hear his own work (as is usual on occasions such as the present) trumpeted forth from the Presidential chair before such an assemblage of eminent men, best capable of weighing their merits or demerits, as that I now see around me. I fear, Sir, that a good deal of the sunny colouring spread by you over whatever I may have been able to add to our knowledge of certain branches of Physical Geology must become toned down to more sober tints when, in future years, what I have been able to do shall be examined by the steady light of the study of the students and philosophers of a future age. It is given to no man so to interpret nature that his enunciation of her secrets shall remain for ever unmodified by the labours of his successors. Nor am I vain enough to imagine that the two subjects for which you have principally awarded me this Medal can be exempt from that which is the common lot of all advances in science. What I have enunciated with respect to the laws of earthquake movements will fundamentally, I believe, admit of little of very radical change by the future advances of Physical Geology; for the laws I have assigned to seismic phenomena come so close to and are such direct consequences of well-understood physical laws as to be, like those laws, immutable; but in details future discovery cannot fail to alter something, and vastly to add to what I have been privileged to announce. For example, it was my own good fortune to ascertain, observationally and experimentally, the depth below the earth's surface whence came the impulse of the first earthquake ever submitted to measurement. That in the case of the great Neapolitan shock of 1857 proved to be only about 8 or 9 geographical miles; but it is highly probable that the depth of the centre of impulse of many great earthquakes may greatly exceed this, and may be found to bear some relation to the height of the greatest mountain-ranges adjacent. Thus my old friend Dr. Oldham, after his examination of the region of the great Cachar earthquake a few years since in North-eastern India, found that its centre of impulse may have been 30 miles in depth from the surface. The views which I have enunciated as to the nature and origin of volcanic heat and energy, though I believe they will be ultimately found to be in the main a true interpretation of nature, must, I expect, be subject to large modification and addition in the future advances of knowledge. Our physical data in their numerical relations are still too defective to enable us to do much more at present than to sketch the general scheme of the laws of volcanic action, which, by the way in which they fit into or explain many natural phenomena in widely diverse regions of nature, seem to afford credentials of their own reality in nature.

In making these remarks I have perhaps already exceeded the limit that properly belongs to an occasion like the present; and in conclusion, let me once more repeat my thanks for the kindness, sympathy, and appreciation with which you have to-day marked your approval of what little I may have been able to do for the advancement of our common object.

Award of the Wollaston Donation-fund.

The President then presented the balance of the proceeds of the Wollaston Donation-fund to Mr. Robert Etheridge, jun., F.G.S., and addressed him as follows:—

Mr. Robert Etheridge,—

I have great pleasure in handing to you the balance of the proceeds of the Wollaston Donation-fund, which the Society has awarded to you as a testimony of their appreciation of your industry and accuracy as a Palæontologist. You have laboured with great success amongst the fossiliferous rocks of Australia, and now you are advancing palæontological science by describing the rarer fossils of the invertebrate series from the Scottish Carboniferous formation. In offering you this distinction, I venture to hope that its reception will stimulate you to further inquiries into the Palæozoic faunas.

Mr. Etheridge replied:—

Mr. President,—

The recognition by the Council of the Geological Society of my labours, by the award of the Wollaston Fund, is both gratifying and complimentary to me. I have been and am still making great endeavours to elucidate some branches of our common science, for your award for which I beg to tender my sincere thanks. It will stimulate me to further exertions.

The systematic study of the British Carboniferous Mollusca, to which I have more particularly confined my attention, has been for many years comparatively neglected, notwithstanding the vast amount of material gathered together through the energy and zeal of local scientific men, many of them distinguished members of our Society.

That any contributions of mine towards this object have met with the approbation of the Society, is in itself a great reward; coupled, however, with the honour you have to-day paid me, it becomes a source of much higher gratification.

Award of the Murchison Medal and Geological Fund.

The President next handed the Murchison Medal to Mr. Warington W. Smyth for transmission to the Rev. William Branwhite Clarke, M.A., F.R.S., F.G.S., and spoke as follows:—

Mr. Warington Smyth,—

The Council of the Society has awarded the Murchison Medal and a portion of the Murchison Fund to the Rev. William Branwhite Clarke, F.R.S., of Sydney, Australia, in recognition of his remarkable services in the investigation of the older rocks of New South Wales, services which have led to a correct knowledge of the succession of the formations in that great country, and which have been of great value to the community.

Mr. Clarke's labours date back nearly half a century, and he had contributed several interesting essays on points of British Geology before he commenced his arduous work amongst the Coal-bearing strata of his adopted country. Influenced by the love of scientific investigation, and aided by a self-reliant and independent character, he surveyed those great depths of rock which brought the local names of Hawkesbury, Wianamatta, and Newcastle before the geological world as landmarks in an apparently anomalous series of strata. His survey, the result of years of patient labour, was so exact, that, in spite of former unsparing criticism, it is now universally recognized as correct; and his deductions as to the relative value of marine and plant-bearing strata in estimating the ages of formations, though disbelieved in former years, have been proved to be consistent with facts since observed in Africa, India, and North America.

Mr. Clarke discovered that there were strata of marine limestones containing Carboniferous *Spiriferi* and *Producti*, and that with these were intercalated beds of coal which presented a mixture of forms of plants. He noticed that there was no break in this great series of deposits, and that *Sigillariæ*, Calamites, and Coniferæ were associated with *Glossopteris* and other genera of Filices, which, had they been found in the typical area of England, would have denoted a

Mesozoic horizon. Subsequent research by other observers in Queensland has produced corresponding results; and science therefore owes much to Mr. Clarke for the consistent and persistent manner in which he has upheld his opinions regarding the age of these Australian Carboniferous series. Labouring amongst the strata below the Carboniferous, Mr. Clarke discovered the presence of Silurian rocks by the existence in them of characteristic Trilobites and Corals, and noticed the unconformability of the Carboniferous to the underlying group; and even in those early days of his work he grasped the important idea that the geology of the typical area of Europe was not exactly comparable with that of Australia.

From his knowledge of the country and of the physical development of the Australian Cordillera, Mr. Clarke was able to enlarge upon the relations of the sedimentary and intrusive rocks; and this led to his discovery of the auriferous quartzites and detrital accumulations of the mountains within 60 or 80 miles of Sydney. Subsequently the possibility of the great north and south range of New South Wales being highly auriferous was impressed upon him by his comparing these mountains with the details of the Oural, the result of the labours of the great geologist, donor of this Medal, and of Keyserling and De Verneuil.

Mr. Clarke's last work on the Sedimentary Formations of New South Wales appeared in 1875, and in it the veteran geologist had the satisfaction of repeating those acknowledged truths which he had elaborated thirty years since.

In asking you to forward this Medal to the Rev. William B. Clarke, I know that I am requiring a pleasant task at your hands, especially when I desire you to express to him the appreciation in which his labours are held by this Society.

Mr. Warington W. Smyth replied:—

Mr. President,—

It is with much satisfaction that I receive this Medal, to be forwarded to the Rev. Mr. Clarke, one among the oldest Fellows of the Society, who joined its ranks upwards of fifty years ago, and has from that time to the present continued his labours in the field of science. Although not personally acquainted with Mr. Clarke, I have had the opportunity, from his being a constant and valued correspondent of our late friend Sir Roderick Murchison, to hear much of the laborious researches carried on by our Medallist in New South Wales. I feel assured that the award of this honour will be duly appreciated in the colony, the Geology of which has been so much advanced by Mr. Clarke, aud trust that it will be a source of pride and pleasure to the veteran explorer in his declining years.

In presenting the balance of the proceeds of the Murchison Geological Fund to the Rev. J. F. Blake, M.A., F.G.S., the President said:—

Mr. Blake,—

In presenting you with the balance of the Murchison Geological Fund in the name of the Council of this Society, I have to express to you our appreciation of the excellence of the Geological and Palæontological services which you have rendered to science during the last few years. The Mesozoic formations of England, which you are still investigating, require all the energies and accomplishments of the palæontologist for their elucidation, besides a great knowledge of practical field-geology. You have undertaken a great task in their description, and I trust that this slight expression of the approbation and sympathy of your fellow geologists may urge you on in your laborious path.

Mr. Blake replied as follows:—

Mr. President,—

I beg to thank the Council very sincerely for the honour they have done me in making this award, and you, Sir, for the kind manner in which you have presented it to me. I do not know that there is any thing that I care for more than the spread and advancement of our knowledge of Nature; and there is no honour I covet more eagerly than such as show, as I take it this does, that I have to some extent succeeded in doing something towards this end. I think I may conscientiously say that what geological work I have done has been the best I have known how to do, or have had the opportunity of doing, though I am continually learning how very much better that best might have been. With regard to the Mesozoic rocks, which form so prominent a feature in English Geology, there is very much yet to be learnt; and the hard and fast lines of the earliest observers have yet to be smoothed down and shaded off, by a study of the physical conditions of the deposits, before we have a complete and artistic picture of the whole. You have assured me, Sir, that the present award is meant not only as an honour but as an encouragement and incentive to me to go on and add, if possible, something more to the picture; and I hope the future may prove that I have received it in that sense.

Award of the Lyell Medal and Fund.

The President next handed to Professor Ramsay, F.R.S., the Lyell Medal and part of the Lyell Fund, for transmission to James Hector, M.D., F.R.S., Director of the Geological Survey of New Zealand, and addressed him as follows:—

Prof. Ramsay,—

The Lyell Medal I have the pleasure of asking you to forward, on the part of the Council of this Society, to James Hector, M.D., F.R.S., and Director of the Geological Survey of New Zealand. It is given to him in recognition of his long and valued services in Geology and Palæontology both in British North America and in New Zealand. Seventeen years ago Dr. Hector communicated a valuable Report to the British Association for the Advancement of Science on the Geology of the Palliser Expedition, and others on the Physical features of British North America, and on the climate of the Saskatchewan district; and in 1861 this Society published his able paper on the Geology of Lake Superior. Having gained great experience as an accomplished surveyor, he commenced his celebrated survey of New Zealand, and the results of it have been to place the geological formation of those remarkable islands plainly before the world. His Geology of Otago, the Reports of the Survey, and his Geological Map of New Zealand (works of great importance) are most valuable contributions to our science. A distinguished naturalist, Dr. Hector has contributed largely to the Botany of New Zealand and to the study of its river-fish, which have remarkable affinities; as a palæontologist, he has not only described the fossil remains of the gigantic birds, but also of the extinct Reptilia of the islands. Impressed with the volcanic phenomena still in action, he has studied and written upon the thermal springs, the extinct volcanoes, and the earthquake phenomena. He has been able to compare the grand developments of the formations of the islands with the European types; and his labours have ever been influenced by that method of research which rendered the founder of this medal so illustrious.

Prof. Ramsay, in reply, said :—

Mr. President,—

I have very great pleasure in receiving this Medal for Dr. Hector, not only on account of his great distinction, but also because we have both been so much engaged in questions of Physical Geology. As a Physical Geologist, I regard him as standing in the very first rank; and his qualifications have been shown, not only in North America, but also by his thorough organization of the Geological Survey of New Zealand, which, under his charge, has attained a position second to none in the world. In Dr. Hector's name I beg to thank the Society for this testimony of its appreciation of his labours.

In handing the balance of the proceeds of the Lyell Fund to the Rev. Thomas Wiltshire, M.A., F.L.S., F.G.S., for transmission to Mr. William Pengelly, F.R.S., F.G.S., the President said :—

Mr. Wiltshire,—

The Council of the Society have awarded to Mr. Pengelly the balance of the proceeds of the Lyell Fund, I may say unanimously, as an evidence of their thorough appreciation of his long and successful labours in the Geology of Devonshire, and his untiring devotion to the great task of extending scientific knowledge relating to the antiquity of man. By his systematic survey and labour in Kent's Cavern, especially, he has not only excited attention on this important subject, but has elaborated facts which will last as long as science. Thanks to his great energy and perseverance, he has kept up a love for geological science in his county; and this has been mainly due to the results of his work among the rocks of Devonshire. In presenting this fund to you for transmission to Mr. Pengelly, I feel that the good opinion which his fellow geologists have of him and his work cannot be sufficiently expressed by me; but I trust that this recognition of his services to science will be felt by him as a slight reward for many years' arduous devotion to Geology.

Mr. Wiltshire replied :—

Mr. President,—

It is a subject of regret to Mr. Pengelly that he is prevented by public engagements from receiving to-day in person the award of the Lyell Trust Fund. Mr. Pengelly, while deputing me to be his representative, has begged me to convey to the Society his high appreciation of the honour conferred upon him. The award, he writes, seems to bring him once more into communion with the spirit of his old friend the founder of the trust, and will be an additional motive for still following up those investigations in Kent's Cavern and in the county of Devonshire which so long were approved of by the late Sir Charles Lyell.

Award of the Bigsby Medal.

The President then handed the Bigsby Medal to Mr. Hulke, F.R.S., F.G.S., for transmission to Prof. O. C. Marsh, F.G.S., and addressed him as follows:—

Mr. Hulke,

The Council of this Society have awarded the Bigsby Medal to Prof. O. C. Marsh, F.G.S., of Yale College, Connecticut, U. S.; and I trust that in forwarding this testimony of our admiration of his abilities and work, you will explain to him that, being a Fellow of the Society, we cannot enrol him amongst our Foreign Correspondents and Members, but that we can offer him the first medal given by one who has laboured long and successfully in the field of American Geology.

The Medal is given in recognition of the great services which Prof. Marsh has rendered to the palæontology of the Vertebrata. He has distinguished himself by studying the fossil remains of nearly every great group of the Vertebrata from the Palæozoic, Cretaceous, and Cainozoic strata of the New World. The field of his research has been immense, but his work has been very correct; and his descriptive and classificatory palæontological writings indicate his effective grasp of anatomical details, and his great power as a comparative osteologist.

Professor Marsh's early work was upon an Enaliosaurian from the Coal formation of Nova Scotia; but this limited field of vertebrate research was soon left for the fossils of the wonderful country in the western territories of the United States. The Cretaceous series yielded the remarkable fossil birds whose examination has been due to Professor Marsh; he added to the knowledge of the Pythonomorpha from the same series by distinguishing the pelvic girdle and the hind limbs. The Pterodactyles have been his especial study, as have also the Mosasaurs of New Jersey and the *Tylosauri* and *Lestosauri* of Kansas. The fossil fish of the Niobrara group have been in part worked out by him. Interesting and important as have been these researches in the lower vertebrates, they are surpassed by Professor Marsh's palæontological contributions regarding the Mammalia of the post-Cretaceous ages. He has described some of the Oreodontidæ, those interesting Artiodactyles of the Miocene of Oregon; and he has illustrated and contributed to our knowledge of the Perissodactyles of the so-called Eocene of the western territories of his country, the genera *Palæosyops, Limnohyus, Lophiodon, Hyrachyus,* and *Limnotherium* being especially studied. His researches amongst the Dinoceratidæ are familiar to every geologist, and most anatomists will admire his labours amongst the fossil Rodentia. Professor Marsh, moreover, has paid great attention to and described fossil species of Crocodilia, Lacertilia, and Glyptosauria, from the same series of strata, whose stratigraphical position is still a matter of debate.

I trust that you will, as a brother palæontologist labouring somewhat in the same field, express to Professor Marsh the appreciation we all have of his interesting and valuable contributions to our science.

Mr. Hulke replied:—

I cannot doubt, Sir, that the award of this Medal will afford Professor Marsh the highest satisfaction. His services to Palæontology have just been so fully enumerated by yourself as not to leave me any thing to add in his behalf; they are so numerous and so important as to mark an epoch in this line of research. The present recognition of the value of his labours will doubtless prove an incentive to fresh work.

THE ANNIVERSARY ADDRESS OF THE PRESIDENT,

Professor P. Martin Duncan, M.B. (Lond.), F.R.S.

In accordance with the annual custom, I commence this Anniversary Address with some short biographies of the more important Fellows of this Society whose deaths have been chronicled during the past twelve months.

David Forbes, late Secretary of the Geological Society, a Fellow of the Royal Society and of the Chemical Society, a most distinguished practical and theoretical mineralogist, metallurgist, and general geologist, was brother to the late Edward Forbes. He was born at Douglas, in the Isle of Man, in 1828, and was partly educated there and at Brentwood, in Essex. Subsequently he entered the University of Edinburgh, and studied chemistry, of which he was very fond as a boy, under Mr. Wilson.

Whilst still very young he was appointed to the superintendence of the mining and metallurgical works at Espedal, in Norway, a post which he held for some years. Capable of enduring great fatigue and full of resources, Forbes travelled far and wide over the country, and studied nature carefully and sedulously. He was especially careful in his investigations of the method of the occurrence of the different minerals in the rocks of the area; and his knowledge of chemistry and petrology enabled him to shed much light upon the causes of the appearance of important mineral species. A careful collector, a most painstaking note-taker, and an admirable analyst, he began to form that collection of rock-specimens, minerals, and analytical results of which he was so proud in after years.

Connected with important industries, Forbes had many opportunities of observing the behaviour of rocks under great heat and pressure, and the study of the peculiar nature of the geology of the country kept these results constantly before him. He became a close observer and a broad thinker upon all those subjects which are connected with physico-chemical changes in rocks, and which at that time were the cause of great debate and of much dogmatism.

His work grew, and in his communication to this Society, entitled "On the Causes producing Foliation in Rocks, and on some observed cases of Foliated Structure in Norway and Scotland," which was read Jan. 31, 1855, Forbes gave an interesting example of the foliation of a blue limestone which rested on mica-schist, near Crianlorich, Perthshire. He noticed that the limestone was completely foliated by the introduction of small plates of mica, so that it often could not be distinguished from gneiss. The foliation was identical with the planes of bedding, and this was the case in the underlying rock; but in the layers above the limestone the foliation was very twisted and irregular. This instance was introduced to illustrate the different views relating to the not invariable coincidence of the lines of bedding and foliation; and Forbes remarked subsequently upon an observation of Keilhau's, where a thick bed of very characteristic gneiss situated amongst other crystalline strata had the foliation, as a whole, developed at right angles to the plane of stratification. He was convinced that a previously existing cleavage-structure often interfered with the rule of the exact coincidence of planes of foliation and stratification, and he considered that the more or less inclined position of the beds during foliation, and the intrusion or approach of igneous rocks, would produce similar anomalies. He demurred to the theory of Darwin and Sharpe that cleavage and foliation are identical, and that they are parts of one and the same process, the former being the first stage of the latter; and he considered them distinct in their nature and causation. He contributed in the same year, 1855, a paper to the British Association on the "Action of Sulphurets on metallic Silicates at high Temperatures;" and also an essay to the Edinburgh Philosophical Journal on the "Relations of the Silurian and Metamorphic Rocks of South Norway." Subsequently, in 1857, he wrote on the chemical composition of the Silurian and Carboniferous Limestones. He clearly defined the chemical action in the production of foliation, and restated the evidence adduced by Sorby regarding the mechanical development of cleavage. Bringing forward many examples of foliation, he explained how they had been the result of the introduction of silicates; and, enlarging upon this part of the subject, he noted that chondrodite, oxide of iron, various sulphurets, and some arseniurets were also of importance in these grand operations.

In the course of this essay, Forbes, after noticing how it is possible to have altered chemical as well as molecular arrangement at temperatures below that at which softening is produced, proceeded to remark upon the apparently foliated structure of certain igneous rocks, which have, of course, been fluid. He considered, however, that this occasional arrangement of "grain" in granitic rocks is not analogous to that layering of volcanic rocks which may be compared to the ribboned structure of glacier ice. In concluding this interesting essay, Forbes summed up as follows:—1. That foliation and cleavage are two distinct processes not necessarily connected, and that those cases where they are parallel or identical generally result from previously induced cleavage-structure. 2. That foliated structure is the result of chemical action combined with a simultaneous arranging molecular force developed at heats below the fusion or semifusion of the rock-masses; and that when we find a similar structure induced in rocks which are known to have been previously in a fused state, this has been developed subsequently to the solidification of such rocks. 3. That the arrangement of foliation is often due to the presence or proximity of igneous rocks, and has a tendency to follow the direction of any lines present, whether of cleavage, of stratification, or of striæ of fusion, following preferably the lines offering least resistance; and lastly, that there are considerable reasons for supposing that the foliated rocks of Norway may be chemically altered fossiliferous strata.

Whilst thus investigating some of the most interesting problems of the day, Forbes, ever an active man of business, became a partner in the firm of Evans and Aikin, nickel-smelters, of Birmingham; and this connexion necessitated his visiting and carefully surveying, in a mineralogical sense, Chili, Bolivia, and Peru. Residing in the midst of the grandest developments of igneous rocks, and constantly engaged in important economical operations, Forbes at last wrote a paper which will always remain as a classical contribution. It was in 1860, and after his return from South America, that Forbes read this important communication before this Society, "On the Geology of Bolivia and Southern Peru." It was the result of observations made from 1857 to 1860, and contained most valuable sections and a map, which give a very excellent idea of the difficulties which the geologist had to encounter, and explained the discrepancies of such previous observers as D'Orbigny in 1842, and Pissis in 1856. After noticing the Tertiary and Diluvial formations of the coast, he explained that, although the coast shows unmistakable signs of recent elevation, this appeared to have been more irregular than to the south; he did not observe any beds of recent shells higher than 40 feet above sea-level. Some guano-beds exist at the same height, and, finding ammonia in them in a state of combination, he considered that it was produced by the action of sea-water, thrown up in the form of spray, on the substance of the beds. He noticed layers of salt intercalated amongst the recent shell-beds, and found them higher up the hills, the salt having dissolved and passed into fissures and crevices. At Arica he noticed sea-beaches at the height of 2000 feet, and explored the saline formations which, stretching 550 miles north and south, have their full development between latitudes 19° and 25° S. They are superficial, often efflorescent, and, besides containing all the salts resulting from the evaporation of sea-water, they have boracic-acid compounds from the occurrence of volcanic craters. He found these saline deposits at three different levels in the great rainless district, at 2500, 7000, and 12,500 feet—the first deposits containing large quantities of nitrate of soda, whilst the borate of lime was found at the highest station. After noticing that these salines rested on old beach-structure, and thus explaining the comparatively recent upheaval of the great plateau of Bolivia, he described the Upper Oolitic beds with interstratified porphyritic rocks which form the Cordilleras de la Costa, and which in Chili form the back range, or Cordilleras de los Andes. Explaining the influence of the contact of the diorites of the region upon the thin-bedded Liassic shales, he noticed the grand development of the series of porphyries, claystones, and porphyry conglomerates which underlie white trachytic tuffs. The subsequent alteration of these conglomerates by silica was considered to be as interesting as the vast amounts of copper found in them, and in one locality they were found to be cut through by a great mass of felspathic lava.

He noticed "the Permian or Triassic formation," whose rocks attained the thickness of 6000 feet, and which are penetrated, upheaved, and altered by the linear eruption of diorite rocks which runs through the whole extent of Peru, Bolivia, and Chili, and which are contemporaneous with the Cretaceous period. So striking was the analogy between these rocks and those described by Murchison, Keyserling, and De Verneuil from Russia that Forbes wrote that it seemed as if he were treating of the same formation. As in the European formation, brine springs and cupriferous sandstones prevail.

The celebrated mine of Corocoro, where the copper occurs as metallic grains or large masses disseminated in beds of sandstone, is in this formation; and Forbes described the remarkable fault which divides the metalliferous district, and which has produced both a vertical and a horizontal disturbance in the original position of the beds. He gave some very cogent reasons for believing that the copper was originally in the beds in combination, and that it was subsequently reduced at the time of the great diorite eruption. After describing the analysis of the strata of Corocoro, and the discovery of vanadic acid in them, he noticed the occurrence in the mines of carbonized wood whose pores contained metallic copper; and also the fact of the discovery of a fossil *Macrauchenia*, which had probably fallen during life into a fissure.

Finally, with regard to these Permian-Triassic strata, Forbes recognized three disturbances in them:—1. Their upheaval by the porphyries of Oolitic age. 2. The protrusion of later diorites. 3. The eruption of the volcanic rocks properly so called.

Passing on to the Carboniferous formation, and noticing its extension near Lake Titicaca, lately surveyed by Alexander Agassiz, Forbes could only refer to its highly fossiliferous character, as war impeded his survey. But he gave a diagram illustrating the grand synclinal folds whose strata contain fossils characteristic of the age in Europe.

Salter advised Forbes to include some strata which the latter had placed as Upper Silurian in the Devonian formation. The true Silurians Forbes found over an area of 700 miles in length from N.W. to S.E., and of from 80,000 to 100,000 square miles. They were shown to form the mountain-chain of the High Andes, rising to an absolute height of 25,000 feet above the sea, and giving origin, by their meteorological effects, to some of the greatest rivers in the world. He showed that D'Orbigny was wrong in supposing the high peaks of this great range to be bosses of granite, and that really they are formed of fossiliferous strata of Silurian age; and our enthusiastic mineralogist proved in person that this was the case at the summit of the mountain Illampu. The resemblance of the Andesian Silurians in physical configuration and in other features to their European equivalents struck Forbes so much that he wrote, "Notwithstanding the much grander scale on which they are developed, the geologist cannot but imagine himself breathing the air of Siluria even before an examination of the rocks themselves confirms the suspicion." He noticed the deficiency of limestones in the lower strata of the Andes, the constant presence of slate, the auriferous nature of the quartz-veins with iron pyrites, and insisted on the occurrence of five disturbances of the rocks. The first was the intrusion of auriferous granite, the second was the porphyritic eruptions, the third the protrusion of the metalliferous diorites, and the fourth and fifth refer to trap dykes and volcanic eruptions.

For noticing this great paper at this length there need be no excuse; it was a model essay, and exhibited the author's geographical knowledge, his correct belief in the metamorphosis of vast masses of rocks, in the influence of contemporaneous and intrusive rocks, and in the grand cycles of physical and chemical change which accompany the evolution of mountain-ranges on the grandest scale.

One of Forbes's most characteristic essays was the lecture delivered before the Fellows of the Chemical Society on Chemical Geology. In it, after asserting that the investigator in the study of Chemical Geology must of necessity call in to his assistance a knowledge of the collateral branches of the natural sciences, he plunged into his subject, and stated that the study of mineralogy, being the alphabet of petrology, shows that many important and common mineral species may have been formed at different times by very diverse processes. He considered that this should warn us against deciding upon any one formative cause to the exclusion of other agencies, and led the argument towards the dangers of receiving, without further knowledge relating to "dissociation," the prevailing doctrines of the origin of the globe and its minerals from the nebular and stellar condition. But, nevertheless, he insisted strongly upon the propriety of considering the known facts regarding pressure, fusion, and chemical affinity under exceptional conditions, in forming an hypothesis relating to the early stage of the globe. He gave it an atmosphere at an early date, and believed that the solid sphere would resolve itself into three great zones. In the first, or crust, highly acid silicates with free quartz would prevail, their bases being chiefly alumina and potash, with minor quantities of soda, lime, and magnesia; below this a second zone of silicates of more basic character and greater density, the bases being lime and magnesia, but with minor quantities of potash; and a still deeper zone of the denser metallic elements in combination with sulphur, arsenic, &c. He imagined that in the first instance we should have the atmosphere next the earth composed of a dense vapour of those compounds which are volatile only at a high temperature, such as the vapour of chloride of sodium. Above this would be carbonic acid, the oxygen and nitrogen, and finally the vapour of water. His idea of the effect of the cooling of such an atmosphere was extremely ingenious, as was also his reasoning upon the manner in which the crust should behave under the influence of cooling and solidification. Finally, after criticising all the data on which these theories can stand, and explaining the difficulties in the way of the aqueous origin of granite, he remarked upon the varying nature of the mineralogy of consecutive plutonic outbursts.

An essay almost as interesting and as suggestive as that just mentioned was written by Forbes in 1869, on "The Nature of the Interior of the Earth." This essay is especially useful, as it places the opinion of Delaunay in opposition to that of Mr. Hopkins regarding the influence of a liquid interior upon precession and nutation, and as it insists upon the possible relative increase of infusibility under great pressure. Forbes, moreover, quotes Palmieri's observations on the tidal phenomena of the eruptions of Vesuvius against the opinion of the merely local source of origin of volcanic phenomena. Finally, after recognizing that the internal specific density of the earth must depend upon something more than pressure, the result of gravitation, he returns to the suggestion made in the paper already noticed, regarding the presence of the heavier metals centrally.

Ever active in scientific inquiry, and labouring in the direction of metamorphic changes, he became an adept in the employment of the microscope in rock-studies; and it was hoped that his great series of analyses would have resulted in a work on petrology.

Much of his time was occupied by the Iron and Steel Institute, of which he was the Foreign Secretary, and also in professional labours in nearly every country in Europe and latterly in Spain. But communications came from his pen, especially to the 'Geological Magazine' and to the Anthropological Society, and he still found time to fulfil the onerous duties of Secretary to this Society. Upwards of fifty papers were written by him, besides his elaborate reports for the Iron and Steel Institute.

A great linguist, a most genial companion and loving friend, and a man possessed of great energy, he was wounded in spirit by the loss of his wife, who was singularly adapted to his tone of mind. Getting into weak health, he died suddenly on Dec. 5th, 1876, and only a few days after he had taken part in a discussion at one of the meetings of this Society.

Elkanah Billings, F.G.S., was born in the township of Gloucester, near Ottawa, Ontario, on the 5th May, 1820, and died in 1876, at the age of 56 years. His family came originally from Wales, and settled in the New-England States, but subsequently removed to Canada. Mr. Billings was educated partly at Ottawa and partly at Potsdam, in the State of New York. Entering the Law Society of Upper Canada as a student in 1840, he was called to the Bar in 1845. He practised first in the town of Renfrew, and afterwards in Ottawa, or Bytown, as it was then called. While residing in the latter place he seems to have found the study of nature more congenial to his tastes than the formalities of the Courts; but whether this was the case or not, it is certain that he began to devote much of his time to collecting the organic remains of the Silurian rocks of the neighbourhood, and amassed in particular a fine and almost unique series of Cystideans and Crinoids, which he ultimately presented to the Museum of the Geological Survey of Canada.

His earliest contributions to the literature of science were a few letters on geological subjects which appeared in the Ottawa 'Citizen;' but the first palæontological papers of any consequence from his pen were a couple of articles "On some New Genera and Species of Cystidea from the Trenton Limestone," which were published in the Journal of the Canadian Institute of Toronto for 1854.

In 1856 Mr. Billings commenced the publication of the 'Canadian Naturalist and Geologist' as a monthly magazine, of which he was both editor and proprietor. Out of a total of sixty-three papers in the first volume of the new venture, fifty-five were either written or compiled by him. Since 1857 the 'Naturalist' has been edited by a Committee of the Natural-History Society of Montreal; but Mr. Billings was always an active member of this Committee, and there is scarcely a volume of the journal to which he did not contribute.

The merit of Mr. Billings's descriptions of fossils and his zeal in their study did not escape the notice of Canada's veteran geologist, the late Sir W. E. Logan. Accordingly, in 1856, Sir William offered Mr. Billings the position of Palæontologist to the Geological Survey of Canada, an appointment which was at once accepted. In the same year Mr. Billings removed to Montreal, the headquarters of the Survey, and entered on the discharge of his new duties, which he continued to perform with equal credit to himself and advantage to the country up to the time of his death.

His principal memoirs during his twenty years of office are an illustrated monograph on the Lower Silurian Cystidea and Asteriadæ, also another on the Crinoidea of the same formation, which together form Decades 3 and 4 of 'Canadian Organic Remains;' the palæontological determinations in the 'Geology of Canada' for 1863; 'Palæozoic Fossils,' vol. i. with 426 pages and 401 woodcuts, published at Montreal in 1865; part 2 of the second volume of ditto, issued in 1874; and 'Catalogues of the Silurian Fossils of the Island of Anticosti,' Montreal, 1866. He wrote numerous palæontological papers, not only for the 'Canadian Naturalist,' but also for the 'American Journal of Science and Arts.' He was an able describer of Corals, Brachiopoda, Trilobites, and Graptolites.

Mr. Billings was for many years one of the Vice-Presidents of the Natural-History Society of Montreal, and was elected a Fellow of the Geological Society of London in 1858.

In 1862 he was awarded a bronze medal in Class 1 by the jurors of the International Exhibition of London, and a similar one at the Exposition Universelle of Paris in 1867. In the latter year, also, he was presented with the silver medal of the Natural-History Society of Montreal as a mark of its appreciation of his "long-continued and successful labours in Canadian Science."

As a diversion from his almost unremitting palæontological researches, Mr. Billings, at different periods of his life, occupied himself with the study of mineralogy and entomology. Among insects, his favourite group was the Coleoptera, and he made an extensive collection of Canadian beetles, which a few years since he deposited in the Museum of the Natural-History Society of Montreal.

Like many other original thinkers, Mr. Billings was entirely self-taught, so far as science was concerned; and those who were best qualified to form an opinion on both points knew not which to admire most, the untiring industry of the man, or the conscientious thoroughness of his work. To show that he spared no pains to increase his knowledge of the science which he made peculiarly his own, it may be mentioned that he learned to translate with ease palæontological essays written not only in the French and German, but also in the Norwegian, Swedish, and Danish languages.

Adolphe Théodore Brongniart was born at Paris on the 14th January, 1801. The son of Alexandre Brongniart, the famous naturalist, he very early renounced the medical profession, and, under the guidance of his father, devoted himself to scientific pursuits. In his nineteenth year he published his first and only zoological paper, containing the description of *Limnadia*, a new genus of Crustacea. In the following year he founded the genus *Ceratopteris* for a curious and anomalous aquatic Fern. In his twenty-first year he published his first palæontological memoir on the classification and distribution of fossil plants. He reviewed in this paper the various plant-remains then known, and grouped them in four classes and nineteen genera. This memoir is really the starting-point of the intelligent study of fossil plants, and from this beginning M. Brongniart continued his labours until, more than any man, he expounded the fragmentary remains of extinct floras, and traced their relations to living plants and their position in the vegetable kingdom. He was singularly fitted for this work; for he already had an extensive acquaintance with the structure and classification of living plants, and he had so digested his knowledge that he was able to utilize it in the exposition of these obscure fossils. Moreover he was specially faithful to facts, and held his imagination in due subordination. He obtained little assistance from previous workers; for the views put forth in illustration of the affinities of fossil plants were in general the strangest dreams that could take possession of an active imagination. All these he swept away, and, by careful induction, reducing the materials to scientific classification, he founded the science of Palæontological Botany.

For some years he prosecuted investigations into living plants, publishing between 1824 and 1827 a new classification of Fungi, a memoir on the natural order Bruniaceæ, and several histological and physiological memoirs. The labours and observations of six years in Palæontology were exhibited in his 'Prodrome d'une Histoire des Végétaux fossiles,' published in 1828, and in his great work, the 'Histoire des Végétaux fossiles,' begun in the same year and prosecuted for some time with great energy. The first volume, consisting of twelve parts, and containing 488 pages of letterpress and 160 quarto plates, was issued within a few months. The further progress of the work was arrested by the author's ill health; and it was not again resumed for a period of nine years, and then only three additional parts were issued, leaving this great work incomplete. The 'Histoire' includes the whole of the Cryptogams, vascular as well as cellular, with the exception of the Lycopodiaceæ, to which the later plates are devoted; and the letterpress is suddenly stopped before the remarkable introduction to this natural order was completed. Numerous separate papers indicate his continued interest in fossil botany, and in 1839 he issued his well-known memoir on *Sigillaria elegans*. This is a good example of M. Brongniart's faithful work, and of the remarkable collection of facts which he invariably brought to bear upon his exposition of any fossil. He contributed, in 1849, to the 'Dictionnaire universel d'Histoire naturelle,' a short and popular review of fossil plants on the plan of his 'Prodrome,' exhibiting their botanical affinities and classification and their stratigraphical distribution.

M. Brongniart's labours were not confined to palæontological botany. Indeed, large and important as these were, they were equalled by his investigations into physiological subjects, and by his publications on systematic botany. In whatever department of the science he worked, he exhibited the same extensive knowledge, and secured for himself the same high position. Early in life he took his place among the first of living botanists.

It is worthy of notice that as M. Brongniart began his scientific life with his labours on fossil plants, so the later days of his life were spent in the study of an extensive series of fruits from the Coal-measures of St. Etienne, which formed the subject of the last memoir he published. Not only did he disclose the evidence of a remarkable and varied gymnospermous vegetation in Carboniferous times, but the structure preserved in these Palæozoic plants led him to suspect the existence of a curious and yet unobserved detail in the organization of the ovule of living Gymnosperms. He did not live to complete these important observations, and several plates referring to them yet remain unpublished. M. Brongniart was in Paris during the siege, and his health suffered seriously in that time of anxiety, danger, and famine. He was never able to shake off the injury his constitution then sustained, though he continued to work daily at the microscope, investigating the remarkable structures he was detecting in the beautifully silicified tissues of the plants of St. Etienne.

M. Brongniart was elected a member of the Academy of Sciences in 1834, in the place of Desfontaines, and in the same year he was appointed Professor of Vegetable Physiology in the Museum of Natural History. In 1840 he was elected a Foreign Member of the Geological Society, and in the following year he received the Wollaston Medal in consideration of his important works on fossil plants. In 1852 he was elected a Foreign Member of the Royal Society, and was also appointed Inspector-General for the Sciences of the University of Paris. He was made an Officer of the Legion of Honour in May 1846.

Carl Friedrich Heinrich Credner, for many years one of our Foreign Correspondents, was born on the 13th March, 1809, at Waltershausen, near Gotha. He received his early education at the Gymnasium of Gotha, from which he went, in 1828, to Freiberg, where he studied for three years, and afterwards passed a year at Göttingen. At the former place the lectures of Naumann and Breithaupt exerted the most influence upon his mind; at Göttingen he especially attended the mineralogical teachings of Hausmann and the lectures on juristic and financial matters, a knowledge of which was necessary for the course of life which he had resolved to follow. Having thus devoted four years to his academical studies, he proceeded to the acquisition of more practical knowledge, and was occupied for a year and a half, under a commission from the Ducal Government of Gotha, in travelling through Saxony, Bohemia, and Silesia. On his return he became mining assistant in Linsenthal, and afterwards, in 1836, received the appointment of Warden of the Mint, and in 1839 of Surveyor of Mines in Gotha. He continued in the service of the Mining department of his native State until 1858, becoming a Mining Councillor in 1850 and State and Mining Councillor in 1854; in the latter capacity he had the whole mining industry of the Dukedom of Gotha under his immediate care. At the same time the great activity and conscientiousness that he displayed in the performance of his duties, and the readiness with which he could adapt himself to business which lay outside the ordinary course of his affairs, led to his being employed in various capacities, and he became Ducal Commissioner of the Thuringian Railway, Director of the Life Assurance Establishment of Gotha, and Managing Director of the Gas-works there. In the management of these multifarious concerns Credner showed so much capacity for business that he attracted the attention of the Hanoverian Government, by which he was called upon, in 1858, to take the position of Superior Mining Councillor and Reporting Councillor in the Ministry of Finance in Hanover. In this important position, which placed under his guidance the great mining and smelting industries of the Harz, the coal-mines, and, indeed, the whole of the mining works of the kingdom of Hanover, Credner remained until the annexation of Hanover by Prussia in 1866, when he passed into the service of the latter State, his first duties in that service calling him to reside for about a year in Berlin, engaged in managing the transfer of the business of the Hanoverian Mining Department into the hands of its new owners. This task completed, he was nominated Mining Privy Councillor and appointed to the charge of the mining district of Halle, which he held from 1868 to the time of his death, which took place, after long suffering, on the 28th September last.

Notwithstanding the great amount of labour entailed upon him by all these official duties, Heinrich Credner throughout his life devoted himself most zealously to the scientific study of several branches of our science, especially mineralogy, geognosy, and palæontology. During his numerous journeys and excursions in various parts of Germany, Austria, and Switzerland, he constantly made collections illustrative of these departments of science; and after his retirement from active life in 1874, he occupied his time in studying and arranging these materials. But his most important scientific work consisted in the investigation of the geology of those parts of Germany which lay more immediately within the range of his professional activity. He published as early as 1847 a 'Geognostische

Karte des Thüringerwaldes,' with explanatory text, which appeared in 1855 under the title of 'Versuch einer Bildungsgeschichte der geognostischen Verhältnisse des Thüringer Waldes;' but his earliest separate publication was an 'Uebersicht der geognostischen Verhältnisse Thüringens und des Harzes,' produced in 1843. Later, in 1863, he published an excellent little treatise, 'Ueber die Gliederung der oberen Juraformation und der Wealden-Bildung im nordwestlichen Deutschland,' and in 1866 a 'Geognostische Karte der Umgegend von Hannover,' with explanatory text. These treatises, although none of them of imposing bulk, display evidences of most careful and intelligent work on the part of the author; and the same may be said of the papers published by him, chiefly in Leonhard and Bronn's 'Jahrbuch,' which treat of geological, mineralogical, and palæontological matters.

Heinrich Credner's merits were repeatedly recognized by the different governments which he successively served. In 1853 he received the Order of Merit, and in 1858 the Cross of a Knight of the Ernestine Order from the Sovereign of Gotha, and in the latter year he received the Prussian Order of the Red Eagle in recognition of his services in connexion with the Thuringian Railway; in 1865 the King of Hanover conferred upon him the Cross of the Guelphic Order; and in 1874, on his retirement from office, he received the Cross of the Third Class of the Red Eagle. His scientific activity also received very general recognition. Prof. Rammelsberg gave the name of Crednerite to a mineral compound of oxides of copper and manganese discovered by Credner himself at Friedrichsrode; and many species of fossils have been named in his honour. In 1872 the Philosophical Faculty of the University of Halle conferred upon him the honorary diploma of Doctor of Philosophy and Master of Arts, and he was an Honorary or Corresponding Member of several German learned Societies. He was elected a Foreign Correspondent of this Society in the year 1863.

Among those with whom he came in personal contact, Heinrich Credner appears to have been exceedingly popular. According to Prof. Giebel, his character stood very high in every respect, and he contributed greatly to the progress of his favourite sciences by the part he took orally in the proceedings of the scientific meetings held in those places where his lot was cast. Two of his three surviving sons are following worthily in his footsteps, and one of them, Hermann Credner, Professor of Geology in the University of Leipzig, already holds a distinguished place among geologists.

In Mr. T. Heathcote Wyndham the Society has lost one of its most promising younger Members. Born at Holbrook, Somerset, Mr. Wyndham was educated at Eton. He matriculated at Oriel College, Oxford, and took a first-class degree in Natural Science in 1865. In 1867 he was elected to the Burdett-Coutts Scholarship, and to a Natural-Science Fellowship at Merton College also in 1867. Feeling that in geology the section of Petrology was not receiving in this country its due share of attention, he visited some of the chief schools of Mineralogy and Petrology on the continent for the purpose of afterwards devoting himself to the study of these sciences. With this view he on his return made a very valuable collection of minerals, and was elaborating a scheme for the establishment of a very complete petrological laboratory in and with the aid of Merton College, where he was in the habit of giving instruction in Chemical Geology and Petrology.

He was also engaged at the time of his lamented death in writing a text-book on the latter subject. Intent upon making himself master of all that had been done both in this country and more especially abroad, and in surrounding himself with all the best and latest appliances, he had abstained for a time from entering upon the field of original research. His public work had therefore been confined to a few slight communications to the Ashmolean Society, and to the results of his two visits to Vesuvius.

Mr. Wyndham was a man most devoted and diligent in teaching, while his courtesy and amiability endeared him to a large circle of friends. Had he lived he must have earned a public reputation in branches of our science where labourers are scarce, and where the loss of one who had succeeded in making himself master of his subject is with difficulty replaced. His death took place on the 11th November, 1876, at the early age of 34.

The following extract from a letter to 'The Times' by Dr. Rolleston, dated Nov. 15th, 1876, will serve better than any thing I can say to show the estimation in which Mr. Wyndham was held :—

"We have lost in Mr. Wyndham a man who for devotion and diligence in the work of teaching was eminent even at a time when such examples are not as rare as they have been. He showed further by his life and conversation that it is a mistake to suppose that a sense of duty to young men with examinations in prospect is incompatible with feelings of enthusiasm for the advancement of knowledge. He was willing to devote his life to the advancement of knowledge in one particular branch of Physical Science, and, had opportunity served, he would have actually done so; but while cherishing these aspirations he was conscientious, unhappily even to over-sensitiveness, in looking to the instruction and necessities of his pupils.

"Mr. Wyndham had faced the difficulty of reconciling the claims of science (which calls upon her votaries day by day more loudly to take up the cross of specialization) with the claims of society in the highest sense of that word, which calls upon all men alike to submit to a multitude of distractions, and to sacrifice possibilities of fame to the performance of duties, often obscure, often invidious. Had he lived longer he might, by continuing to combine abnegation of self with labour at learning, have shown that the incompatibility of rival claims lessens with their elevation.

"Being, as he was, a reformer, it was often his duty to advocate measures which were necessarily distasteful to many among us. But on these occasions, as in all other social undertakings, Mr. Wyndham illustrated the old and not now sufficiently recollected saying, 'Un gentilhomme est toujours gentilhomme;' his courtesy and respect for the feelings of opponents in controversy being as remarkable as his singularly many-sided considerateness for his allies in any joint enterprise, whether of a serious or merely of a recreative kind.

"Had he lived he might have both earned and obtained a permanent public reputation; as it has unhappily fallen out, the memory of him will be limited by the smaller, yet still extensive, circle of his attached personal friends. Within that circle it will not be short-lived."

Christian Gottfried Ehrenberg was born on the 19th April, 1795, at Delitzsch in the province of Saxony. Up to his fourteenth year he attended the school of his native place; in 1810 he obtained a free scholarship in the Pforta Academy, where he had several men of note (as, for example, Leopold von Ranke) among his associates; and he left this institution in 1815 to study theology at Leipzig, in accordance with his father's wish. But even in the midst of his classical studies at the Academy, he had already devoted his hours of leisure to investigations in natural history; and this bent of his mind led him, when he had been a year at the University, to exchange the study of theology for that of medicine. He completed his academic studies in Berlin, where he attained his degree of Doctor of Medicine on the 5th November, 1818, his inaugural dissertation bearing the title "Sylvæ mycologicæ Berolinenses."

In the two following years we find the young doctor engaged with his friend Hemprich in sketching plans for a great journey of investigation to some distant part of the earth; and the wishes of both of them were fulfilled in the year 1820, when General von Minutoli, who was on the point of starting on an antiquarian journey into Egypt, requested the Berlin Academy of Sciences to recommend him two young naturalists as companions. The Academy selected Ehrenberg and Hemprich. Their journey in common extended into the Libyan desert as far as the oasis of Jupiter Ammon (Siwah); but after their return to Alexandria, the two naturalists quitted the General's expedition in order to carry on natural-history investigations on their own account. They traced the Nile upwards as far as Embukohl in Dongola, made an excursion into the Fayoom, returned to Cairo in 1823, and then examined the northern coasts of the Red Sea and especially the Sinaitic mountains. While Hemprich conveyed the collections they had made to Alexandria, and remained in that city awaiting remittances, Ehrenberg remained for six months in Tor, occupying himself principally with the corals of the Red Sea.

The two naturalists afterwards undertook a third journey, into Syria and Cœlosyria; they penetrated as far as Baalbec, and reached the snowy summits of Lebanon. Their further journey was commenced in 1825; it carried them through Arabia to Loheia, and across to Massowa on the Abyssinian coast. Here Hemprich fell a victim to fever; and his friend committed him to the grave on the small island of Toalut. Ehrenberg then made an excursion to the hot springs of Eilet, and returned by Kosseir and Alexandria to Europe in 1826. During the six years of his absence he lost nine of his European companions by death. In the Memoirs of the Berlin Academy for the year 1826, Alexander von Humboldt gave a preliminary report upon these great travels and the important collections which had reached Berlin through Ehrenberg and Hemprich.

In the year 1827 Ehrenberg was made an Extraordinary Professor in the University of Berlin, and on the application of Alexander von Humboldt obtained, through the minister Von Altenstein, the means of making known the scientific results of his travels. In consequence of this, two volumes of 'Symbolæ physicæ,' with copperplates representing mammals, birds, insects, &c., appeared in the years 1828–1834. Unfortunately circumstances were unfavourable to a continuation of the work.

A short historical sketch of the first part of his travels appeared in 1828 under the title "Naturgeschichtliche Reisen durch Nordafrika und Westasien in den Jahren 1820–26, von Hemprich und Ehrenberg." In 1827, Ehrenberg had already published a description of the deserts in the Memoirs of the Academy. He also published some of his observations upon various subjects in different periodicals, *e. g.* on the Manna of the Tamarisks, on the Scorpions and their geographical distribution, on the Monkeys of Sennaar and Kordofan, on the peculiar noise heard on Djebel Nakuss among the mountains of Sinai, and on the Corals and Acalephæ of the Red Sea.

The journey to the Ural and the Altai and to the Chinese frontier, undertaken in 1829 by Alexander von Humboldt at the desire of the Emperor Nicholas, principally for the purpose of bringing to light the mineral riches of the Russian empire, has been well described by Gustav Rose, who, with Ehrenberg, accompanied Humboldt.

On his return, Ehrenberg devoted himself exclusively to microscopical researches; and in 1830 he published a memoir on the organization, classification, and geographical distribution of the Infusoria, of which Cuvier speaks as follows in the 'Analyse des travaux de l'Académie Royale de Paris:'—"This discovery entirely changes our ideas, and especially upsets many systems; it is one of those which constitute epochs in the sciences." This memoir was followed by contributions which were continued until the year 1835. In 1838 appeared the great work 'Die Infusionsthierchen als vollendete Organismen,' with 64 plates, for which and for his geological researches this Society conferred upon Ehrenberg the Wollaston medal as a special distinction. As early as 1836, Ehrenberg had discovered that the polishing-powder known as tripoli abounded in fossil organisms, and that the polishing-slate of Bilin, near Teplitz, contained innumerable siliceous shells of similar creatures. The same result was obtained by the microscopic examination of the so-called "edible earths" from various localities. This occurrence of fossil organisms was soon afterwards demonstrated by Ehrenberg in older formations, as is evidenced by his memoirs 'Die Bildung des europäischen, libyschen und uralischen Kreidefelsens und Kreidemergels aus mikroskopischen Organismen' (1839), and 'Ueber noch jetzt zahlreich lebenden Thierarten der Kreidebildung und den Organismus der Polythalamien.' In the year 1841 he demonstrated the presence of organisms in the peat-beds in various parts of Berlin (Museum, Friedrichsstrasse, and Karlsstrasse), and gave an impulse to the technical employment of these, and of the Infusorial earth of Ebstorf in the Lüneburger Haide, as, according to the reports of old writers, an earth serving for polishing-purposes could be used for the manufacture of light building-stones, capable of floating upon the water, and the dome of the mosque of Saint Sophia, the celebrated structure of the Emperor Justinian, is composed of such stones. With the hearty cooperation of the then director of the Royal Porcelain Factory, the Mining Privy Councillor Frick, Ehrenberg had stones manufactured from the Berlin material, which proved from their porous nature to be very useful, and were employed by the architect Hoffmann in the construction of the cupola of the Museum.

In 1845, at the request of the Mining Department, Ehrenberg made investigations on the diffusion of the infusorial tuffs in the Eifel; in 1847 he published his "Beobachtungen über Passatstaub und Blutregen," in the Memoirs of the Academy of Berlin; and this was followed by a long series of papers in the 'Monatsberichte.' In 1840 he had prepared his 'Microgeologie,' which appeared in 1854, with 41 copperplates. The first part of a continuation of this work, relating specially to America, appeared in 1856.

A new field is opened by his works on the Greensand and the illustrations of its organic life (1855), and his communications on the gradually advancing knowledge of immense quantities of microscopic organic forms in the lowest Silurian deposits near Saint Petersburg (1852–62). His attention also was vividly excited by the recent investigations of the sea-bottom; so that, by the receipt of samples of soundings from the most different regions, he was enabled to investigate thoroughly the microscopic organisms of the depths of the sea. In 1872 he published a revision of these, illustrated with 12 plates, which was followed in 1875 by a work on "die fossilen Erd- und Felsproben des Meeres und Süsswassers aller Länder, und die Polycistinen-Mergels von Barbados" (with 30 plates). Thus, nearly to the close of his long life, which took place on the 27th June in the year just closed (1876), he showed no relaxation in his activity.

From the year 1839 Ehrenberg was an Ordinary Professor in the Faculty of Medecine. From 1842 he was Secretary of the Physico-mathematical Class of the Academy of Sciences, of which he had been a member since 1827. In 1839 king Friedrich Wilhelm III. conferred upon him the great gold medal for Art and Science; and at the same time the Crown Prince gave him a gold medal relating specially to Ehrenberg's discoveries; the Civil Class of the order "Pour le mérite" counted him as one of its members from the time of its establishment by king Friedrich Wilhelm IV.; and foreign honours were not wanting in recognition of his scientific merits.

Quite in the evening of his life he was gratified by the receipt of the large gold medal founded by the Dutch Academy of Sciences at Amsterdam in honour of Leeuwenhoek, the discoverer of the Infusoria, and conferred for the first time unanimously upon Ehrenberg.

Ehrenberg's work was always exact, and his microscopic delineations, done with no first-class instruments, are magnificent. Several of his genera have lasted on, in spite of zoological progress and fashion; but, as might have been anticipated, great alterations have been necessary in his classification of the Foraminifera, Protozoa, and Cœlenterata. Few geologists now remain to recollect the astonishment with which they received, in 1836, the assertion that large masses of rock, and even whole strata, are composed of the remains of microscopic animals; but this assertion has been confirmed and extended largely by Ehrenberg's further labours. Those bearing especially upon marine deposits were collected together by him in his celebrated memoir read in 1872; and in it may be found carefully elaborated descriptions of microscopic life of the sea-bottom from all zones, and admirable remarks upon the relationship of the present and past faunas, and the connexion between the progressing and former geological deposits. His industry was untiring; and so great was the range of his work, that those who are about to investigate the conditions and microscopy of the sea-floors need to search in his pages before they commit themselves to announcements of discovery.

Henry Clark Barlow, M.D., F.G.S., was born at Newington Butts, Surrey, on May 12th, 1806. In 1822 he was articled to an architect and surveyor, but relinquished the profession in 1827, and after studying for some time in Paris, was matriculated as a medical student in the University of Edinburgh, where he took the degree of M.D. in August 1837, but without any intention of following the profession. In the spring of the next year he went to Paris, and in 1840 made his first tour through Belgium, Germany, and Holland. In 1841 he went for the first time to Italy, where he remained nearly five years, and in December 1845 returned to England, bringing home a large collection of notes of travel, sketches and drawings of the various scenes he had visited. In 1846 he went again to Italy, and, after spending two winters in Florence, extended his travels to Athens and Constantinople, returning through Hungary and Austria. In 1849 he again visited Germany, passing some time in Berlin, Dresden, and Prague, examining and making notes on the various picture-galleries, museums, &c. of these cities. In 1850 appeared his first printed paper on Dante, "Remarks on the Reading of the 59th Verse of the 5th Canto of the 'Inferno;'" and from this time his whole life seems to have been devoted to the study of the 'Divina Commedia.' In 1852 he was again in Paris, examining the codices in the various libraries there, the result of which, and of his collations of above 150 other MSS. in Italy, Germany, and England, are given in his 'Critical, Historical, and Philosophical Contributions to the Study of the Divina Commedia,' published in 1866, "in Commemoration of the Sixth Centenary of Dante Allighieri," which had been celebrated in the previous year. It had been originally proposed to hold a festival in Italy in commemoration of the great poet in 1859, but it was very judiciously postponed in accordance with the recommendation of Dr. Barlow: after pointing out that the year 1859 had no "correspondence either with Dante's birth, death, or any remarkable event in his life," he urged that the proper year for such a demonstration would be 1865, the six-hundredth anniversary of his birth. A full account of the proceedings of the three days (May 14th, 15th, and 16th) at Florence, in which the Doctor himself took a prominent part, was published by him anonymously in the following year, 'The Sixth Centenary Festivals of Dante Allighieri in Florence and at Ravenna. By a Representative.' The festival at Ravenna having taken place in June of the same year, in consequence of the discovery of the bones of Dante in the latter city, about ten days after the termination of the great festival of Florence, an account of this most interesting discovery was forwarded to the 'Athenæum' (September 9th, 1865) by our enthusiastic Dantophilist.

Dr. Barlow's numerous contributions to the literature relating to Dante and Italy were very numerous, and a bare enumeration of those printed during the last five and twenty years would occupy much space, without mentioning the brochures, all bearing more or less on the same subject, which he had from time to time printed, chiefly for distribution among his friends and literary acquaintances and all the continental libraries he visited in his travels.

Although thus engrossed with the study of the grand old poet, Dr. Barlow was much attracted by the very varied scenery through which he constantly passed, and with its relations to geology. He collected specimens wherever he went, and studied our science carefully. Although a silent attendant at the evening meetings of this Society, he could follow most of the papers read; but this did not constitute all his enjoyment on those occasions. He liked the breadth of our science, the liberality of the opinions of its students, and the freedom of our discussion, accompanied, as it is, by a closeness of argument, which he used to state was typical of the great master he followed. A most pleasant companion and a thoroughly courteous gentleman, Dr. Barlow appreciated the work this Society is carrying out; and he is now amongst the list of our benefactors, having left a legacy with which the Council can deal, not necessarily to reward or encourage individual geologists, but to add to the usefulness of the Society.

By the death of Baron Wolfgang Sartorius von Waltershausen, on the 16th October last, the Society has lost one of its most devoted cultivators of some of the more exact branches of our science. Born at Göttingen in 1809, he evinced at an early age a strong inclination for the natural sciences, and in particular for mineralogy. Whilst following out his university studies he attended as member of a special class the course of instruction given by the illustrious Gauss on Astronomy, Geodesy, &c. This it was which in a great measure induced him, during a scientific tour of Europe in 1834–35, to carry out a series of magnetic observations at a number of different localities. The great object, however, which he now brought into prominence was a thorough and accurate investigation of Mount Ætna. Provided with a handsome fortune, and prepared by a long course of study, he held that no more valuable contribution could be made to geology than an exact map and description of the present state of that great volcano—such data, in fact, as would supply a standard of comparison for many years to come. Very few scientific undertakings on so great a scale have ever been attempted by private enterprise. No past work relating to this district, except the shore-line given in the English Admiralty Chart, could be depended on; and a geodetic triangulation had to be carried out over the whole area, and a base-line measured on the shore near Taormina. He had the advantage at first of the cooperation of Professor Listing, and afterwards the aid of Dr. Peters, the Danish astronomer, and of Messrs. Cavallari, Roos, and Zobel. Making Catania his chief abode, he would stay away in different parts of the mountain, and especially at the Casa Inglese, upwards of 9000 feet high, for weeks at a time. The toil of tramping over the lava-fields and the great vicissitudes of climate told upon his health, and serious illnesses interrupted the work, which was nevertheless perseveringly carried on till 1843, when the enthusiastic vulcanist returned to the north, and, after visiting Iceland and Great Britain, addressed himself from 1845 to 1861 to the reduction and publication of the materials brought from Sicily. The chief result that has come before the public is his magnificent 'Atlas of Ætna,' consisting principally of a map on the scale of 1 to 50,000, a beautiful example of copper-plate engraving, in which the special lava-streams of the last several centuries are distinguished, each of them by appropriate shading, and of accompanying views, which were carefully checked for their leading lines by instruments of precision*.

Appointed Professor of Mineralogy and Geology at Göttingen, to which University he had in 1847 presented his fine cabinets of minerals and crystals, Waltershausen continued from time to time his investigations of Ætna's minerals and rocks. His sketch and atlas of Iceland, 1847, led to a comparison between Sicilian and Icelandic phenomena in the work 'Ueber die vulkanischen Gesteine in Sicilien und Island und ihre submarine Umbildung,' 1853.

In 1861 he gained the prize of the Haarlem Society of Sciences by his treatise 'On the Climates of the present and of the former World, with especial reference to Glaciers.' But the great descriptive work that was to be the parallel to the 'Atlas of Ætna' was never completed; and we learn that, although a large mass of MSS. has been left by him, only a portion of it is in a state ready for the printer.

Those who have enjoyed the acquaintance of our late Associate will have observed that by the side of his adherence to the severer sciences, there was within him a strong leaning to poetry and the fine arts. The mansion which he erected in the outskirts of his native town (a transplanted specimen, as it were, of the Sicilian Norman) was somewhat typical of these tastes.

No one, however, can have seen him either in the cabinet or on the

* A valuable copy of the original map, on a larger scale, viz. 1 to 30,000, was presented by the author to this Society.

mountain-side without admiring that gentle and right loving spirit which could burst into an enthusiasm like that which, for above forty years, directed and brightened the great and leading labour of his life.

It is indisputable that the science of Geology has never been so sedulously cultivated as at the present time; and it is evident to all who are acquainted with its literature that the vast accumulations of carefully observed facts which are recorded year after year are environed by theories and hypotheses of great importance and interest.

Isolated no longer as a merely descriptive science, Geology is now very dependent upon those branches of knowledge which are exact in their nature; and with them it increases in importance, in the breadth of its philosophy, in the height of its aspirations, and in its applicability to the wants of mankind.

That our science should progress in all its branches, at the present time, is a matter of great congratulation and satisfaction; for year after year the great leaders of Geology—the men who consolidated the facts and enunciated the theories upon which its superstructure rests—complete their task in the great evolution of human knowledge. They have left us one by one, and it might have happened that, in the absence of its great supporters, the science had suffered a languid decadence. But the illustrious dead live on still in science as ever-present energies; they are embodied in those methods of thought which characterized them and their works, and which will influence Geology as long as civilization endures. Our gratitude to them should never cease, and should ever be expressed by the constant and pertinacious endeavour to continue their labours and to support this great and useful Society.

They found the well of geological truth calm, quiescent, unruffled, and its depth unknown, in an age of great intellectual agitation, when prejudices and superstitions scared away many a student from the virgin spring. They broke through the trammels of public opinion and braved a social opposition, happily now almost inconceivable, and drank long and deeply at that fount of knowledge. Ruffling often enough the clear surface, still the waves of true progress extended their circles, sometimes crossing, sometimes becoming apparently inextricably confused; but in the end advancing harmoniously in all the beauty of truth, and will persist in their advance as long as we (their followers) fulfil our trust and duty to our science.

It has been stated, and with much truth, that Lyell modified his opinions during his later years, and that Murchison, the type of the stratigraphical geologist, lived long enough to admit the arbitrary nature of all the schemes of the classification of formations; but it must not be forgotten that they still retained their methods of investigation, and that, whilst influenced by new facts and the evident fallacy of many cherished hypotheses, they kept prominently in their minds the fundamental doctrines of uniformity and continuity in nature, and of the succession of a series of physical geographies on the surface of the globe. These important beliefs, when modified to meet the requirements of abstract physics and biology, form the basis of our science; and as they represent the everlasting influence of their great propounders, so their necessary modifications and amplifications indicate the direction and nature of the present satisfactory development of geological knowledge and thought.

Strict uniformitarianism, as taught by Hutton and his followers, asserted that the past changes on the surface of the globe resembled those which are now occurring in kind and degree. The first part of this proposition is philosophical and true in every respect; and whilst it relegates hypothetical forces and supernatural catastrophes to the limbo of scientific sand ropes, it places Geology in correlation with the exact sciences. But it has long been believed that the second part of the dogma is, in the abstract, incompatible with the first, and that it is opposed to some of the simplest yet most logical deductions from the principle of the conservation of energy. Causing a monotony in geological reasoning, requiring phenomena observable at the present time to have their application strained unreasonably, and inferring the lapse of inconceivable time, it has gradually been modified or discredited. It is giving way to a school which insists upon the recognition of a scientific cosmogony, which attempts the study of the mutations of the globe from the beginning, from the example of stellar and solar changes, and which considers that the principal factors in terrestrial alterations (the solar heat and the residual heat of the earth) are energies undergoing only a definite amount of reversible and more or less irreversible transformation. Change, in the language of this school, is work done; and the term "degree" relates to the time in which equal amounts of work were completed.

The gradual evolution of the globe and the alteration in its configuration as a dynamical system have been brought about during a definite lapse of time which bears a relation to the diminution of the energy—the legacy of its stellar condition. Moreover, as the consecutive occurrence of the formation of continents, deep oceans, and mountain-ranges, indicating repeated upheavals, subsidences, and curvings of the superficies of the earth, are measures of force and of a corresponding dissipation of energy, so the constant denudation of the surface, which is mainly the work of the great centre of our system, represents an equivalent loss of its power. It follows, under certain reservations, that the degree of change must have diminished in exact relation to the progressive loss of energy in the two material systems; or, in other words, that in the earlier geological ages the extent and rapidity of the successive changes were greater than in the modern example, that the rigidity of the globe was less, that the internal heat and its expression in temperature at the surface were greater, and that the meteorology was such that the wear and tear of world-wide nature was larger in its annual amount.

The reservations which interfere with the definiteness of this theory are important and interesting, but the compensatory results they indicate must have diminished commensurately with the more positive terrestrial changes. Their importance and interest depend on the appreciation of the amount and kind of the reversibility of the transformation of energy over and above that which is indicated in the grand natural phenomena already noticed. For instance, after recognizing that the vast curvatures of the outer part of the globe, of which there is evidence in the formation of the successive oceanic depressions and continental areas, are work done, and that the sharper foldings and curvings recognizable as mountain-chains are also instances of reversible transformation of energy, it is necessary to consider whether their formation was accompanied by an acquisition of available kinetic energy which could in any way influence the degree of successive changes.

The great curves (the geosynclinals and geanticlinals of Dana) are of all ages, and implicate the hardest rocks, and they appear to have moved in the superficies of the globe as a succession of waves, vast in extent. Indicative of persistent, yet diminishing contraction of the globe, their formation must have been more rapid in the earlier periods. They were apparently irregular in their course, one wave interfering with another, as heat was conducted to the surface through masses of mineral matter of different temperatures, density, and conducting-power, and having very different relative amounts of contractility. The depth of rock which was implicated was very great; and whatever time may have elapsed during the formation of any curve, there was motion of the substance of its component strata. Doubtless the direction of the movement was often opposite; but it was frequently direct and progressive, or oblique, and finally more or less at right angles to its original plane. It may be assumed that the rate of movement, always relatively slow, has been slower during the later ages; but there has been corresponding momentum on the grandest scale, and also pressure and shearing accompanying the motion.

There is some positive evidence, besides that of an inferential nature, that the rate of motion of these very large curves was greater formerly; for atoll and deep-barrier-reef coral formations are not recognized in the Palæozoic and Mesozoic series. They are noticed first of all in the Tertiary deposits. But all the coral formations of previous ages appear to have been either fringing reef or shallow-water banks. They formed lenticular-shaped masses of limestone, or strata of very even thickness over considerable areas, but not of vast depths, and enclosing more or less supporting mountains. Atoll formations require a subsidence of a more or less submerged mountain at a rate commensurate with the upward growth of the reef-building coral, due allowance being made for the wear and tear of the reef by the waves. If the subsidence is too rapid, the reef is drowned; and if it is carried below the 30-fathom line, the coral grows no longer. If the subsidence is too slow, no depth of limestone results, and the coral island is formed. At present the rate of subsidence is unequal; but, on the whole, as gleaned from the number of islands, it is much less than formerly. The great age of atoll-building has passed, and it may be said to have been fully developed towards the close of the Miocene period. and to have been more or less synchronous with the production of the great geanticlinal land-movements which accompanied the continental elevations and mountain-formations of that period.

It is conceivable that the shear of the particles of the moving strata, and especially of those of masses of deep, unstratified, hypogene rocks, and the compressing influence of the synclinally curving zones, produced an amount of metamorphosis and vulcanicity in addition to that which has been the regular attendant of the direct influence of residual heat. This certainly would prolong the time of secular cooling, and would cause it to be irregular.

It will be necessary to revert to this subject after considering the less hypothetical but very cognate results of some of the phenomena of the minor curvings of strata within the great curvatures.

A study of the results of the orographical surveys, and of sections of such great mountain-masses as the Alps, Himalayas, and the Rocky Mountains, affords abundant proof that these areas extended far beyond their present lateral boundaries before the action of those forces whose intensities are measured by the curving, folding, reversing, and upheaval of the strata. In fact every mountain-range affords proof of the operation of forces which have moved the originally horizontal strata into a smaller horizontal space or breadth. There has been motion on a large scale, and the constituents of the strata have been forced together in opposite directions, sometimes one lateral force determining, by its superiority, obliquity of motion, and even absolute progression of the whole. They have been made to occupy increased vertical dimensions, and there has been movement of one stratum over another and of particle over particle.

In assuming the increased vertical bulk, gravitational energy has been produced; and in the shear (the result of all the movement over and above that which has occurred in opposite directions) there has been an acquisition of certain amounts of available kinetic energy; and these, bearing a relation to the rate of movement, are to be measured by the altered direction of the particles (as in slaty cleavage), the deformity of masses (as in the altered shape of stones and fossils), and by the metamorphic condition of the whole. A certain amount of heat must have always been produced; but usually it appears to have been simply sufficient to assist percolating waters, charged with minerals and gases, in the production of metamorphosis. There are no evidences of the production of a temperature sufficient to fuse rock in great mountain-masses of slate, where there are abundant proofs of the former motion and pressure; and on the south side of the geological axis of the Himalayas the so-called crushed rock is environed by the results of ordinary metamorphism alone. Nevertheless very considerable masses of rock must have had their temperature raised.

But it has been ably argued that volcanic phenomena are in relation with the formation of the great curvatures of the crust and of mountain-masses.

Thus Mallet has taught that crushing of the crust occurs as it follows down after the shrinking nucleus, the contraction being due to its constant loss of heat; and that, through the work done in that crushing, there has been the production of a definite amount of heat that is productive of vulcanicity.

The nucleus supplies the greatest amount of the heat which is gradually dissipated at the surface of the earth; and as it is hotter than the crust, it contracts most for a given amount of cooling. According to this theory, the rock crushes under the combined influence of gravitation and lateral thrust; and the amount of any heat which may be produced must bear a relation to the rate of movement of the particles of the rocks implicated. The rate of movement would appear to have been greatest at the periphery, or in the highest curves of the mountains; but it has already been noticed that they do not afford indications of the production of much heat and certainly not sufficient to fuse rock; so that if vulcanicity is to be developed lower down, but still at no great depth, increased gravitational energy must compensate for the insufficient rate of movement.

So far as mountains are concerned, the greatest stress, shear, and pressure must exist at the junction of a synclinal with the base of the great anticlinal ridges of the few anticlinoria which are on the line of strike of the greatest mountain-masses (which are almost invariably in synclinoria).

The phenomena of vulcanicity are seen there in some instances, and in one they are to be observed on a grand scale. It is in one of those interesting areas whose geology science owes to the admirable intelligence and perseverance of our American brethren*. The Uinta Mountains, which cover a part of the country east of the Sierra Nevada, west of the great plains and south of the North Platte, are a great range carved from an anticlinal fold, the axis of which has an easterly and westerly bend, and is more than 150 miles in length. It terminates abruptly against the Wasatch Mountains on the west, and is cut off by the short abrupt anticlinal of Junction Mountain on the east, the latter having its axis in a north and south direction. The axis of this long flexure has been elevated about 30,000 feet above the level of the sea, and 28,000 feet above the adjoining country. From flank to flank the flexure is about 50 miles. The whole consists of a high, long, and broad tableland, and upon it are elevated valleys and peaks; but it is a vast anticlinal with prodigious faults at its margins and along the line of strike on either flank. The sharp lateral flexures lead to faults, and on the north side there is a downthrow of 30,000 feet. In the plateau region of the same area, of which a section and the bird's-eye view comprehending the plateau north of the grand cañon of the river Colorado of the west may be considered typical, there is an anticlinal outline to the structure of the district, the curve being flat, broad, and faulted along the strike; and the rest of the district consists of huge blocks faulted and tilted in broad masses, the whole having had an original anti-

* Report on the Geology of the Eastern portion of the Uinta Mountains. Department of Interior, U.-S. Geol. Survey, J. W. Powell. Washington, 1876.

clinal conformation. Still more westerly are short ranges of older rocks, of metamorphic crystalline schists with Palæozoic beds on their flanks, constituting the Basin province whose streams empty into salt lakes, the Great Salt Lake being amongst the number. Their conformation is remarkable in the extreme; for it is a land of parallel and almost vertical faults, separating monoclinal ridges and bounding narrow synclinals, and of ranges built of faulted and dislocated rock-masses with an imperfect anticlinal arrangement.

The able surveyor of this broken country remarks "that the structure of the Basin range system stands in strong contrast with the Appalachians; for in the latter corrugation has been produced commonly by folding, exceptionally by faulting, and in the former commonly by faulting, and exceptionally by folding. The regular alternations of curved anticlinals and synclinals of the Appalachians demand the assumption of great horizontal diminution of the space covered by the disturbed strata, and suggest lateral pressure as the immediate force concerned; while in the Basin ranges the displacement of comparatively rigid bodies of strata by vertical or nearly vertical faults involves little horizontal diminution, and suggests the application of vertical pressure from below." The opinion of the describer is clearly that there has been a vertical uplift along lines of fault; but it would appear that the general configuration may have been one of long, low anticlinals separated by short synclinals, that the faulting has been subsequent, and that the ranges have been the result of downthrows of different magnitudes.

These three provinces run one into the other; and the present condition relates to a great series of movements implicating the whole, lasting more or less since the Cretaceous epoch, and accompanied by enormous denudation. The upheaval was greatest in the district first noticed, and least in the last. It is clearly an area on which volcanic phenomena should have prevailed on Mr. Mallet's theory. In fact the complexity of the country, to use the words of the surveyor, "is greatly increased by reason of the floods of lava which have been poured out here and there over the entire area, and now and then from the Cainozoic up to the present time. And all these floods of lava, all these thousands of eruptive mountains, thousands of 'mesa' sheets and cones testify to a period of great volcanic activity, while the region was in fact a great continental area." But the lava-flows and the volcanic eruptions proceeded *pari passu* with the upheaval and faulting, and they lasted on possibly close to the human period.

Considering all the data, it is quite possible that much of the energy which has produced this vast series of flows and eruptions was kinetic; for the movements over the area were frequent, and lasted through the period occupied by the volcanic phenomena—that is to say, from the end of the Cretaceous series to the formation of the Bridger group. Nevertheless it is reasonable to admit that all the phenomena may have been caused by hydrothermal action, assisted by the relief given to deeply seated and highly heated rocks, by the diminution of their pressure as the vast anticlinal system was formed. In this case there would be dissipation of potential energy, and in the former a certain amount of maintenance of available kinetic energy, during a long period.

It appears that some of the grandest volcanic phenomena relate, in a more or less complicated manner, to the vast primary geosynclinal and geanticlinal curves already noticed; and it is possible that the loss of residual heat may be compensated for by much which is produced during the movements of the masses implicated in them. But in attempting to realize this possibility, the minor example of the production of heat during the development of mountain-chains can afford the only grounds for argument, which is therefore unsatisfactory. But the influence of the curving of great depths of the crust upon the more heated zones below, in increasing the pressure in one area and in diminishing it in another, and therefore in altering the fusibility, appears to be very important. If it is admitted that at certain times oceanic tracts are areas of subsidence, and continents are areas of more or less continuous elevation, the floor of the ocean is the upper part of a geosynclinal, and the land of a corresponding geanticlinal. The cord of the arc of these curves is so long that any movement appears to be directly upwards and directly downwards. Where the two curves join, as they are really produced by resolved tangential thrust, there is a region of stress and irregular movement. Its position is close to where there is a sinking sea-floor and a rising land; and that is the line peculiarly favourable to the development of volcanic cones in all their grandeur. There is along such a line a belt of deeply seated rock in what may be termed a condition of unstable equilibrium, liable to faulting and to ready penetration by volcanic pipes. On the one side there is the downward curve causing increased pressure on the subjacent masses of deep crust, and on the other this pressure is much less and the opportunities for fusing all the more. The position of the plane of instability close to the sea affords opportunity for the passage of water, thus adding to the possibility of vulcanicity on a great scale. The volcanic belt encircling the Pacific is a striking instance of a line of vents along the margin of two vast curves; and there are many similar examples in the former distribution of volcanoes. Take the instance of that vast mass of igneous rocks, even now 3500 feet thick, with interstratified lake-beds and with numerous pipes indicating its subaerial origin, which is called the Deccan Trap of Western and Central Hindostan. Covering now more than 200,000 square miles, it is situated geologically on the confines of the Cretaceous sea, and it covers an old land-surface produced by the uprise of the Cretaceous rocks in great breadths during the initiatory period. Of the same general age as the volcanic outbursts of the west of the United States in Uinta, it testifies to the influence of the slower and grander movements of the crust, in occasionally producing secondary results, but in the main rather furthering the dissipation of the potential energy of the globe. So far, then, as the changes in the earth and in its rocks are concerned, there does not appear to have been that great amount of compensation, and practically they may be said to have diminished in degree irregularly, period after period. Under these views strict uniformitarianism is impossible in degree.

There are some thoughts which arise in the mind during the consideration of the time of accumulation of vast depths of fossiliferous strata, associated with no evidences of metamorphism; these may be stated, probably for the first time, as follows:—

The production of heat during the contraction of the outer rock-zones of the globe being an inevitable and necessary physical phenomenon, its consideration opens out some important lines of thought, which may strongly influence geological theories. The questions arise —Is the temperature of the deeply seated rocks in mines and wells or in the midst of mountain-masses the immediate result of the conduction of heat from the hypothetical nucleus? Is this temperature an evidence of residual heat and simple cooling alone, or is it almost entirely due to the resulting stress, shear, and chemical action? Many facts are in favour of the latter mode of origin of the heat of the outer zones of the earth during the later geological periods; that is to say, that the original heat of impact and chemical combination, after producing the deformation of the globe and perhaps the grand outlines of the primary geosynclinals and geanticlinals, ceased, even in the early ages of organic nature, to be of sufficient importance to produce more than a very slight elevation of the temperature of the rocks for many thousands of feet below the surface. The details of the rate of increase of temperature with depth do not point everywhere to a regular rate of increase according to the laws of heat, and the limited depth of the seismic foci testify against the ordinarily received theory. Moreover, in examining many great series of sedimentary strata which could only have accumulated at great depths, and which must have been tens of thousands of feet below the surface (for instance, during the Palæozoic ages), the absence of the effects of commensurate and contemporaneous heat is often very striking. The absence of metamorphic rocks, or of the evidence of the action of an elevated temperature, is notorious, where at the present time, in corresponding situations, they should be distinct enough; and such absence relating to the remote past is most significant. The structure of the Himalayas to the north of the central gneissic axis is that of a vast series of comparatively unaltered sedimentary fossiliferous strata, curved, folded, sometimes reversed, and upheaved. On the south such strata are not to be recognized, except on the flanks, and the foldings, contortions, and dislocations are in excess. There are great breadths there of mountains without a fossil, and metamorphism prevails. There is probably no difference in the age of the two zones, and the lowest beds of the northern zone must have been quite as deeply situated in the crust, during the Secondary and Tertiary epochs, as the corresponding strata of the southern slope. The anomaly is explicable, as is also the condition of the deeply seated unmetamorphosed rocks of other hills, by dismissing the influence of conducted residual heat as of little or no importance, and by acknowledging that the rate of movement within the curving rocks determined commensurate physicochemical changes.

It must be acknowledged that a permanent increase of a few degrees of the temperature of the waters would kill off many species, and that the whole fauna and flora would cease to exist were the average heat double what it now is. The same result would follow a moderate increase of the heat of the soil with regard to the plants. Now if the estimated amount of heat radiated year by year, after conduction from within, relates entirely or mainly to a former much greater annual average, all being residual in its nature, the question of the possible lapse of time since the surface was cool enough to permit of life arises, and it has been ably used in argument against absolute uniformitarianism. It appears to those who have seen great depths of fossiliferous deposits in several formations, in more than one country, that, leaving alone the inorganic sediments, the time which they took to accumulate is inconceivable. And the more the aid of the naturalist is sought the greater does this lapse of time seem; for the rate of growth of many Mollusca is now pretty well known, and this information gives a minimum in a calculation regarding successive deposits which is always startling.

With regard to the great thicknesses of deep-sea deposits, I have satisfied myself, from late researches, that the rate of deposition is extremely slow. Thus an electric cable was laid down in the *Globigerina*-ooze region, and six years after a considerable coral-growth had taken place on it. Some of the living calices were close above the cable, and therefore the deposit had been infinitesimal in the time. Again, there are large slow-growing Echinoderms, Corals, and Spongida in place in many chalk series, and it is evident that the foraminiferal and sedimentary deposit was infinitely slower than their growth.

The mind fails to acknowledge the possibility of such a limit of time as the physicist is bound to insist upon consistently with the usual theory of the secular cooling of the globe. In considering this subject in all its bearings, it must be remembered that the depth of the outer substance of the globe implicated in curves of all kinds is relatively very small; and it may be fairly urged that all this deformation, associated as it is, and has been for ages, with much rigidity is not commensurate with an amount of resolved tangential thrust which has accompanied a high superficial temperature.

This theory, which is certainly well worthy of consideration, is eminently favourable to uniformitarianism in both of its developments. As it states that the heat of the superficies is kinetic mainly, or is representative of a degraded energy, it of course gives abundant time to the most exacting geologist*.

A question has arisen frequently of late years, whose solution depends to a certain extent upon those just considered, and which relates to the degree of the denudation and earth-sculpturing of the past.

The sum of the meteorological activities and of the comparative rapidity of the crust movements during any period determine the degree and amount of its denudation. Hence there are many subjects which require separate investigation before the theory of a diminishing or variable degree of denudation during the past ages can be fairly stated. Some have been so constantly before the geologist of late that it is only necessary to mention them. For instance, the

* I presume that the effects of tidal retardation have been compensated by secular contraction.

diminishing and variable solar energies; the relative inclinations during time of the polar axis to the plane of the ecliptic; and the influence of geological changes on climate. But one important subject has scarcely been debated; and it refers to the possible changes in the amount and pressure of the atmosphere during the history of the cooled globe.

It is an interesting question, and one which has practical bearings, whether the earth has lost or gained atmosphere, and therefore has been environed by less or more moisture. The teaching on the subject of the amount of the present atmosphere and its cosmical relations is amusingly contradictory; and the student of this part of meteorological physics (which, moreover, is of transcendent importance) need well despair. He may glean from various authorities, from Laplace to Quetelet, that the rotating globe, revolving around the sun and progressing in space with the solar system with enormous velocity, carries with it an atmosphere which may be 33 or 45 to 50 miles, or nearly 200 miles in height; that at a distance of 40 to 50 miles the gravitation of the atoms of the air just balances the force of their repulsion; that all beyond is vacuous, and yet, in spite of the absence of gravitational energy and in the presence of increasing tenuity, the distant zones of the atmosphere cling to the globe!!

The notion of the vacuum beyond this indefinite boundary may cease to be credited, for we read in elementary works "that the medium of light is certainly material, and has mass;" but although we are taught that there all matter is subject to the law of universal gravitation, there is a doubt propounded whether this "material" is a gravitating substance. Astronomers fill space with cosmical matter in an infinite state of division, and every successive advance in solar physics demonstrates higher zones of moving matter environing the previously limited gaseous envelope. Hence amidst all this indefinite and contradictory philosophy the geologist, acknowledging the enormous importance of meteorology in relation to general atmospheric pressure and vapour-holding, must take his own course of thought.

He may readily believe in a universal atmosphere whose tenuity is greatest between the great attracting bodies, and that the position of greatest tenuity, as well as the height of the atmosphere which can move with the planet, bears some relation to its mass and temperature. He need not believe that the distant zones, where gravitation is counteracted by expansion, are carried round with the globe at a rate which would sweep all their particles into space, and produce in a short time such a diminution of atmospheric pressure as would cause the oceans to turn to dry land. He may believe that, moving in the midst of an elastic medium of great tenuity, the globe receives compensatory amounts for what it has left behind. But as the sun, in spite of its heat and chemical force, must attract more than the globe in the long run, the terrestrial atmosphere must steadily diminish in height. The earth may be supposed to be getting in the same condition with regard to the sun as the moon has passed through with regard to the earth. That our satellite had an aqueous atmosphere we are bound to believe, on account of the vulcanicity to which it formerly was subject; but now there is only the faintest and most doubtful trace of a film in one of the deepest craters on its surface *.

Doubtless the moon, of whose early fellowship the lowest sedimentary strata have yielded proofs, in the form of tide-rolled pebbles, lost her atmosphere partly to the earth, but by far the most of it must have gone sunwards.

Reasoning, then, by analogy, the earth should have had a higher atmosphere and probably more of it in the past; and this would be very compensatory. A slightly greater atmospheric pressure would counteract the greater possible rate of evaporation; and this compensation rather adds to the probability of the theory. With more aqueous vapour and with the action of a more energetic sun, subaerial denudation may have progressed far above its present average rate. Moreover the greater movable atmosphere would absorb much of the heat of the hotter sun, and would modify its action on the surface; and, on the other hand, a greater diffusion of equable temperature would prevail, and towards the poles there would be prolonged twilight.

A greater rainfall and more rapid movement of the lower zones of the atmosphere would result; and as the supply of moisture must have been greater, there is no reason why the local glacialization of high mountain-ranges should not have occurred. The impossibility of the occurrence of masses of ice on the sea-level, or for some thousands of feet above it, or at the poles, must, however, be admitted.

In passing from these subjects it is worthy of remark that stratigraphical geology has long since entered its synthetic stage, in accordance with the usual progression of scientific knowledge. In the early days of the science it was necessarily analytic, for typical

* See Matthieu Williams, 'Fuel of the Sun.'

areas were requisite for the comparison of others; and to be of real use their strata, series, and formations had to be accurately separated and defined. Physical and biological breaks were carefully sought; and as they were facts of a certain value, and as their appreciation was and is still of the greatest importance to the geological surveyor, they materially assisted the progress of exact study. At first the inability to discover such breaks in the succession of rocks was disappointing, and was considered to be anomalous; but as research was conducted further and further from the typical districts, it became evident that such discontinuities could not have been contemporaneous universally, and that their absence tended to increase the belief in the doctrine of continuity in ever evolving nature. The discovery of the imperfections of the typical successions in remote districts, the influence of the literature regarding missing strata and formations, and relating to those which, although found elsewhere, do not exist in the typical areas, gave a great importance to the study of "passage-beds." Their careful examination soon carried conviction that they were not geological anomalies, but that they were links in the chain of evidence regarding the variety of the synchronous changes on the surface of the earth, and of the irregularity and localization of the grand movements of its crust.

Palæontology, useful at first to distinguish strata by determining characteristic fossils, became the most important scientific aid to those who sought rather to link together consecutive series than to separate them. As it passed out of the influence of the false hypothesis of repeated universal destructions, re-creations of totally different forms, and of the invariable restriction of species to small areas, Palæontologists greeted the discovery of the phenomena of the former and recent geographical distribution of animals and plants as the first glimmer of light leading to the great doctrine of evolution. The old ideas gave place to those of the continuous modification of species under changes in the external physical conditions, of the possibility of migration, of the vast horizontal and vertical distribution of many forms, of the persistence of types, and of the succession of similar types on the same areas. Taken as aids to the generalizing tendency of modern Stratigraphical Geology, these theories have not only qualified the terms "equivalent" and "horizon" in reference to our science, but have stimulated the belief that, with the progress of world-wide surveying, the broken succession of strata and formations, so requisite as the alphabet of Geology, will soon cease to be a fact.

The struggle has been sharp between those who have maintained the importance of the study of foreign geology in comprehending the value of the particular evidence afforded by the rocks of the typical European districts, and those who were indisposed to acknowledge intermediate formations; and the literature of the doubtfully placed strata has been polemical enough on the stratigraphical as well as on the palæontological side. Now, however, every careful essay bearing on the relations of the geology of remote countries to those nearer home, brings new matter, complicating the old histories of the globe at present, but still to afford light in due time.

So much has been so ably written on the absence of a sufficient physical and also of a satisfactory biological break between the Cambrian and Lower Silurian formations of the United Kingdom, that it is only necessary to notice how impossible it is, according to the strict doctrine of uniformity, to apply, in explanation of those old rocks, stratigraphical arguments which would hold good in later Mesozoic and Tertiary geology. The smaller number of faunas and the comparative paucity of species, coupled with the occurrence of more frequent crust changes in the Cambro-Silurian age, render the rules and dogmas of the classificatory geologist dealing with the later ages comparatively inapplicable. In the early history, the physical breaks of lithological change (for instance, the occurrence of pebble-beds, of intercalated limestones, each of which would be of definite importance in the later history of the globe) are subordinate to the persistence of the genera. Whilst in the later history of the globe transgressive strata and the same lithological succession are often accompanied by a gradual change in generic and specific types, the reverse generally occurs in the older rocks.

Lonsdale's Devonian, still a stumbling-block to the pure stratigraphist dependent on breaks, and primarily recognized from the intermediate nature of the species of its fauna, has had its absence proved over vast areas; but its palæontological separation from the Upper Silurian and Carboniferous is usually, but not invariably, as remarkable as the world-wide distribution of its species. De Koninck's last work on the Australian Palæozoic deposits brings the Devonian of that distant country most remarkably in relation with that of Europe and America; and doubtless the Devonian superposed on Silurian in lat. 82° N. will tell the same story.

The Carboniferous and the Permian, once believed to be so distinct, are becoming more and more inseparable in such remote areas as the west of the United States, from the association throughout the conjoint series of species of plants and Mollusca which are sharply restricted to one group of strata or the other elsewhere. So the Permo-Carboniferous of one part of the world affords a proof of the earlier appearance of certain genera of plants, which in another are characteristic of the upper and separable formation. This early appearance merges into a persistence in the Australian and Indian peninsular areas; and in the latter the Mesozoic element of the flora extends into the Mesozoic series without the intercalation of the true Carboniferous marine deposits so characteristic of the lower part of the coal-bearing strata of Eastern Australia.

There is some difficulty in separating, except on arbitrary grounds, the Carbo-Permian from the Lower Trias, in consequence of the evidence afforded by the Himalayan sections of Stoliczka. In the area surveyed to the north of Simla the grand outlines of the sedimentary formations are to be traced beyond the central gneiss, and the Carboniferous is found not to be succeeded by a Permian. Some 2000 feet of Upper Trias of St.-Cassian age rest conformably on rocks which include species of Brachiopoda which are characteristic of the Carboniferous Limestone of Europe, and are involved with them in the great curvatures and reversals which produced a great physical break. This break is not, then, immediately after the last Palæozoic deposits and according to the European type, but after the Upper Trias.

The Rhætic series, with *Megalodon*, rests unconformably on the curved Carboniferous and Trias. The interest of this particular type, related as it is to the succession in Australia and in the Indian peninsula, was increased by the discovery by Dr. Waagen of the association of *Goniatites, Ceratites*, and *Ammonites* in a limestone-bed in the lower half of the upper division of the Carboniferous formation in the North-west Himalayas, the accompanying Brachiopoda being Carboniferous *Producti* and *Athyrides*. All the considerations relating to the persistence of the Palæozoic flora, the earlier appearance of the Mesozoic forms in remote localities, the commingling of Mollusca very differently distributed vertically in Europe, and to the general conformity until the end of the Upper Trias with *Halobia Lommeli*, *Orthoceras salinaria*, and *Ammonites floridus*, enhance the theory of the local nature of the Permian and its usually associated Lower Trias. Whatever may be the direct value of this theory, it involves a very important point in practical palæontology, namely, that it is not absolutely necessary to seek for the unbroken succession of faunas and floras in strata which are in normal sequence. The continuity of the biological succession was not through the Permo-Trias, but through a series in which the Permian was wanting.

There are some remarkable palæontological facts relating to the distribution of forms in those distant areas where there is little homotaxis with the typical areas of Europe.

The number of the species in the Himalayan Carboniferous identical with those of the corresponding European strata is very remarkable, and the Brachiopods are often larger in size. In North-east Australia some forms characteristic of the Carboniferous Limestone of India and Europe are found in the underlying Devonian; and although this formation is absent in the Himalayas, there is a more or less definite Carboniferous facies in the fossils of the so-called Upper Silurian, or those rocks which underlie Carboniferous strata conformably.

The Upper Trias in the Himalayas, which I have just noticed, has a very European facies of the St.-Cassian type, and contains four European Brachiopods, besides *Halobia Lommeli*, *Ammonites floridus*, and *Orthoceras latiseptum*; and it underlies the Lower Rhætic unconformably. This has the Dachstein bivalve and a *Dicerocardium*, and is overlapped by the succeeding Upper Rhætic, whose fossils are most remarkable. Some are special to the area, others are identical with those of European deposits, such as *Terebratula gregaria*, *Rhynchonella austriaca*, and *Pecten valoniensis*; and the rest tell the same story as the plant-bearing series, namely, the earlier appearance of types which characterize later deposits elsewhere.

Thus in these Himalayan Upper Rhætics there are *Rhynchonella variabilis, Terebratula punctata*, *Ammonites macrocephalus*, *T. obtusifrons*, *Ostrea acuminata*, *Gervillea olifex*, *Avicula inæquivalvis*, *Natica pelops, Chemnitzia coarctata*. In these rocks there are, then, the foreshadowings of the Middle and Upper Liassic and Oolitic faunas of distant localities. The series is covered by a bituminous limestone containing a mixture of Middle and Lower Lias fossils with a *Nerinæa* of Oolitic facies.

The marine Trias, Rhætics, and Lias are not represented in the neighbouring areas of the peninsula of India, which appears to have been dry land during those ages, and its fauna and flora were very persistent. In Europe there is the Upper and Lower Triassic succession, and that wonderful fossiliferous series above the Rhætic strata which, under the term Infra-Lias, reaches to the base of the arenaceous beds of the zone of *Ammonites Bucklandi*.

The break between the Jurassic and Cretaceous series is filled up by the Tithonian and Purbeck-Wealden in Europe and in Continental India; and the absence of marine Neocomian is very notable over very large areas where there is a well-developed Upper Greensand.

It was expected that the Upper White Chalk of Faxöe age would be found merging transgressively into beds with an admixture of Cretaceous and Tertiary fossils; but this has not happened. The most careful examination of the Tertiary strata remote from the Cretaceous deposits has only yielded species of *Belemnites* in Europe and in Australia; but the Cretaceous facies of the Tertiary Echinodermal fauna of this last province is very remarkable. Some years ago the singular affinities of the Lower Cretaceous and Miocene coral faunas of the West Indies were noticed; and the late dredging-expeditions have produced evidence of the persistence of Cretaceous types of Corals, Sponges, Echinoderms, and Foraminifera. Nevertheless, wherever the upper strata of the Cretaceous are calcareous, there is a great physical and biological break. But these discontinuities are sensibly diminished at the margins of the old Cretaceous ocean and sea-floors, where the siliceous element replaced the organic deposit. There, in several localities, most interesting relations have been shown to exist between the faunas and floras of the Cretaceous and Lower Tertiary periods. In Khasia, in the South-eastern Himalayas, the Cretaceous is a littoral deposit with coal-seams and a marine fauna which in Europe would be characteristic of strata from the Gault to the Upper White Chalk inclusive, and the Gasteropoda, as is seen in the Indian area, give a Tertiary facies. It merges imperceptibly into sands, shells, clays, and finally into Nummulitic limestone. The palæontological break is, however, complete except in facies. To the south-west the marine Cretaceous beds of the south of India are eminently Tertiary in the facies of their Mollusca, but still the break is vast. To the west, where the great trap covers the Cretaceous rocks and underlies in some places the Nummulitic, some most interesting land-surfaces have remained. Some are intertrappean freshwater lake-floors, which abound with species of *Physa*, *Limnæa*, *Paludina*, and *Melania*, and their age is Postcretaceous; and others (the Lameta beds, for instance) are Cretaceous land-surfaces with the same genera. These considerations add great interest to the American succession.

Allowing for the great sameness of shape of fresh- and brackish-water shells of all ages, which deprives them of any very great palæontological value in determining horizons, it is still very interesting to find in the deposits of the Western States of North America, which have the same relation to typical Eocene and Cretaceous as the Nummulitic has to the Deccan Trap and Lameta series, species of the genera *Limnæa*, *Planorbis*, *Physa*, and some referable to a special type of *Melania* (*Goniobasis*). These American deposits are the debateable land where the stratigraphist, petrologist, and the vertebrate, invertebrate, and botanical palæontologist will vainly seek to find hard and fast lines by which they may correlate and compare the various horizons with those of the typical districts. It has been shown that the closely allied species of these genera are found in two successive but indefinite groups of rocks, th lowest of which is the last expression of the Cretaceous formation. This country, of which the surveys of Montana, Wyoming, Uinta, and the other localities are comprised by Hayden in his magnificent work, has a lignite in the series which may be roughly called Cretaceous and Cainozoic; and thus there is evidence of a more or less continuous terrestrial condition during a period when emigration and extinction were modifying the Mesozoic fauna and flora. What a paradox was the discovery of the association of a doubtfully Cretaceous *Corbicula* and species of *Ostrea*, *Vivipara*, and *Goniobasis* (which might be Secondary or Tertiary in age) with the bones of a large Dinosaur (the *Agathaumas sylvestris*), whose remains were stuffed and covered with leaves of Dicotyledons of strikingly Tertiary facies! The stratigraphical line which should separate the Cretaceous from a Tertiary deposit was inferior to the position of these remains; the Dinosaurs are presumed to characterize no higher horizon than the Cretaceous; the shells may belong to any zone of the long-existing brackish-water conditions; and the plants indicate an admixture of Cretaceous and Tertiary forms when examined by the deceptive light of remote and presumably equivalent deposits. Although the weight of the evidence from the last researches of Meek places the deposit in the Cretaceous formation, still the discovery of the remains of tortoises of Eocene type (such as *Plastomenus*) and fish of the genus *Clastes* in association with Dinosaurian remains complicates the question. It is evident that the Black-Butte horizon is one where an Australian-like jumble of so-called characteristic types protests against the lingering desire to believe in universal and contemporaneous changes, and in the inevitable death of the living forms with the physical change, and indicates that certain plants and animals originated in earlier times and lived longer and into later ages than the hard-and-fast stratigraphist and palæontologist will concede.

An attempt has been made to establish a zone intermediate between the European Cretaceous and Eocene, under the title of Palæocene; and the flora of the clay-beds of Gelinden, so abounding in leaves of *Dryophyllum*, has been compared with remote recent, and neighbouring and remote Cretaceous floras. It has been shown by Lesquereux that a series of closely allied forms of oaks, under different names, flourished in the days of the Quader-Sandstein, in the Upper Cretaceous of Belgium, in the Cretaceous of Nebraska, and in the Eocene of Europe and the Lignitic series of the United States. Moreover analogous types occurred in the Miocene of Europe and America, in the Pliocene of California, and in the recent flora of the United States. This prevalence is quite in accordance with the long duration of the genera and families of plants so evident in the preceding ages of the globe. But a careful examination of the main features of these Cretaceous and Tertiary floras on both sides of the Atlantic explains that they were irregularly isolated, in spite of the persistence of a few types with great vertical and horizontal ranges*. Thus there is a marked difference between the Cretaceous plants of Greenland and those of Dakota; and whilst in the lower members of the one there is 38 per cent. of Cycadeæ, there is not one satisfactory species in the other. These Cretaceous floras are, moreover, deficient in the palms which constitute such an important feature in the North-American and European Eocene. Again, although the Eocene or Lower Cainozoic flora of the Western States has a facies and a generic distribution remarkably different from that of the underlying Cretaceous, the Cretaceous types reappear in the Miocene of the same district, and their principal genera still predominate on the eastern slope of the North-American continent. In fact the Cretaceous flora, comparatively unrepresented in the Eocene as yet known to us, had some of its genera in the lower part of the Miocene, more in the Upper Tertiaries, and they culminate in the recent period. Whence came the plants of the Western-American Eocene, indicating as they do a warmer climate than that of the probably temperate Cretaceous area of Dakota? Their alliance to those of the Palæocene and other zones of European Eocene plant-bearing strata is scanty, but there is a certain similarity of facies. The Himalayan Eocene flora contains no genus which is not represented in modern India; and there are of course palms, cycads, figs, horse-chestnuts, and soapworts, so it has the general facies of the former and present age.

* See the admirable results of the Survey of the Western Territories, U. S., and the essays of Lesquereux.

These considerations, and those which arise during reflections on the great depth of the Eocene series and their singularly varied nature, rather tend to the belief that different but tolerably closely allied floras were in diminishing contact where the North Atlantic and Pacific now exist.

The study of the Cretaceous plants of Europe indicates the isolation of their area from that of America; and thus the story told by the whole of the floras down to the present day is that, in spite of alterations in climate, and in the relative distribution of land and sea, there has been no vast extinction, and therefore no very wide physical break, but that, from the days of the genesis of the Dicotyledonous flora in Secondary times to the present time, groups of plants have been localized in provinces, and that the isolation has lasted longer in some areas than in others.

The impossibility of drawing a line between the Upper Eocene and the Lower Miocene of Europe led to the adoption of the term Oligocene; and that it has a significance is shown in the varied nature of its strata, the great depth of Coral Limestone in the area so ably described by Reuss, and in its remarkably intermediate fauna. Finally, in pursuing this subject of geological continuity, it may be stated that the conditions of the Miocene, with its vast land-surfaces and the crust movements which initiated the Pliocene in some parts of the world, have prevailed down to the present time in others.

Most geologists have speculated and philosophized over the grave significance of the facts and opinions thus sketched out; and most may feel well satisfied at the results they have led to during the last decennia. It is no longer necessary to believe in the repeated destructions and new creations so dear to the geologists of not many years ago, but, on the other hand, to acknowledge a continuous connexion between the movement of living things over the globe during the process of distribution, and the extent, frequency, and rapidity of the alterations in the relations of land and sea incident upon the lingering on of the earliest energies of the globe. But, assisted as our comprehension of these important coincidences has been by the theory of evolution and by the hypothesis of the origin of species by descent, variation, and modification under the influence of external physical conditions, the mind still longs for more definite facts by which to prove the position of the principal genetic areas and the direction of emigration. It is, moreover, dissatisfied with the belief that all the wonderful art in nature, the limited direction of variability, the parallelism of form, ornament, and physiology in contemporaneous and successive groups of fossils sometimes widely separated zoologically, are due to the action of physical changes and heredity alone. It is true that the physical change is not fortuitous, but relates to the inevitable; and thus its influence on life is part of a great philosophy; but is that sum of the action of the mysterious energy on matter which we call life simply passive, and only alterable by external conditions? According to the prevailing theory, if all the external conditions remain the same, the individuals of a species, or the species of a genus, will retain their classificatory characters; but if change takes place in the physical conditions, or if alterations occur in the struggle for existence, then the variability will bear a relation to the intensity of the opposing forces. Extinction, or the survival of the fittest, results, and this is accompanied by loss of specific identity. Is this all the truth? Is there not some positive energy in living things which, if uncontrolled and uninfluenced by externals, will produce progressive changes?

From the examination of the faunas and floras of provinces which have been long under the same physical conditions (and the remark holds good during the geological ages) it is found that particular and dominant groups are represented by numerous species; that is to say, isolation under the same physical conditions is accompanied by variation and the production of new species. Madagascar and Australia, with their numerous forms of Lemuroida and Marsupialia, the numerous species of the same genus associated in such faunas as the Sivalik, and the extraordinary assemblage in the Miocene of the Bad Lands, and many others, may be brought forward in illustration. The variations and specific changes have apparently been uninfluenced by competition; and yet there has been a definite and often parallel order of change of method of life and accompanying structural change in the faunas of similarly placed but remote areas. The old South-African reptilian fauna advanced during its isolation so that a foreshadowing of the dental arrangement of the higher Carnivora took place. In Australia the ultimate expression of the variability of nearly all the groups of the rest of the world has taken place in animals of one subclass which have been isolated for ages. It was not competition or the influence of external conditions alone that enabled the structures of the Marsupial to meet the habits and the method of life of the Quadrumana, Bats, Insectivora, Rodentia, Herbivora, Carnivora, and even of the Pachydermata, but the operation of a law of variation in definite directions, potential in the organism and irrelative of physical conditions.

If great variation and yet persistence of the generic type is assumed to have taken place during the long isolation of faunas and floras, a totally different series of organic mutations may have ensued on their coming into mutual contact, and when the struggle for existence became intense; so that in any great area, where one large and well-defined country had few alterations in its conformation during a long period, and another close by suffered from many during the same lapse of time, the opportunities for the greatest excess of specific and generic change ought to occur on the subsequent junction of the two areas. This comparative instability of districts in the same great area is instanced remarkably in India; for during the long periods of land conditions in the peninsula, the repeated upheavals and subsidences of the Himalayan zone, and probably of a large area to the north, rendered land-surfaces rare there. Africa south of the Sahara was probably a stable area during many of the alterations of the relative level of land and sea of the north and of Europe. The want of relation between the grand physical changes of the west and east of the United States is of the same importance in the argument. If this be the correct interpretation of nature, those areas in which there has been the least relative instability should have the simplest faunas, and those which have undergone the greatest, and which here transgressed on other provinces, should have the most complex. Granting that the typical geological districts of the United Kingdom, France, and Germany have been involved in crust-movements more frequently than the areas of Africa, India, and Australia, there is an explanation of the relatively involved nature of the faunas which first attracted the attention of geologists.

There are some other considerations regarding the appearance of forms in the geological ages, which the zoologist and comparative anatomist ally with groups which must have been long and are still separated widely geographically. The Marsupials of the Trias and Oolites of Europe and those of Australia, the Didelphia of the Paris Eocene and those of the present American fauna, the Lemurs of the Eocene of Europe and of the American Tertiary deposits, and those next in zoological range, the American Marmosets and the Platyrrhini, are instances. Was there a genealogical descent in the received zoological line in these separate instances? The Marmoset may have descended from the American Eocene Lemurine animal, and the Platyrrhini also; but it is quite probable that the Lemurs were never in the line of the Catarrhini, and that the early Cynocephali, the ancestors of all Old-World Monkeys, were modified Carnivora.

Could not the Triassic Marsupials of Europe have had a direct reptilian genesis, whilst those of Australia were in the line of the Monotremes, and these with the Ornithoscelida? Can, in fact, more than one method of origin have occurred? If it were so, some of the greatest difficulties in the explanation of the distribution of plants and animals would be removed.

These difficulties have been materially increased by the acceptance of the dogma of the extreme antiquity and persistence of the present continents and oceans, and by novel and unnatural ideas regarding the method of migration. The vast extent of the Tertiary marine deposits, the evidences of the great alterations in the relative level of land and sea since the Pliocene age, and the presence of long parallel ranges of more or less submerged mountains in the great Pacific, in the Indian Ocean, and in the Atlantic, prove to the geologist that comparatively late in the history of the globe the progressive wave of continuity of land has influenced distribution. On the other hand it is known that animals and plants, whatever may be their powers of locomotion at some time of their life, do not move readily beyond their districts, and cannot do so unless there are all the necessary surroundings of food, soil, and temperature. To the majority a roundabout land journey must be out of the question; and there must have been continuity of land at one time with the necessary accessories in order that closely allied species should be found in remotely separated localities.

In conclusion, it is necessary to notice the vast strides which, thanks to the chemist, mineralogist, and microscopist, have been made in the study of petrology. Not very many years since the metamorphic origin of serpentine was as sturdily opposed as was the possible metamorphosis of clays into gneissic rocks. The nomenclature of volcanic products was in the greatest confusion, and there was a hard-and-fast line drawn between those of the past and those of the present time. Now the sciences of optics and chemistry, assisted by the mathematician, are gradually revolutionizing the old notions of the fixity of crystalline rocks, and are expounding their progressive and retrogressive mutations, which are in relation to denudation, aggregation, subsidence, pressure, and hydrothermal action.

Our science has revealed in its wonderful progress that the inorganic mass crumbles, alters, and returns into its pristine form in often-repeated cycles, but that the organic world advances in its development, never returning along its path. This evolution is not the result of a passive obedience to the unprogressive in nature, but relates to that at present incomprehensible environment, which is indicated to the geologist by the beauty and order of form, the mimicry of ornament and structure in remote groups of fossils, the compensation in natural phenomena on the grandest scale, and by the proofs which he has, after a long study of his science, that there has been for ages a definite connexion between the great movements of the superficies of the globe and the occurrence of consecutive aspects of animated nature.